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Society and the Environment: a Soviet View

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Society and the Environment: a Soviet View

PROGRESS PUBLISHERS
MOSCOW

Translated from the Russian by John Williams

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This book was prepared by Progress Publishers in cooperation with *Social Sciences Today*, a journal of the USSR Academy of Sciences.

Коллектив авторов

«ОБЩЕСТВО И ОКРУЖАЮЩАЯ СРЕДА.
ПОДХОД СОВЕТСКИХ УЧЕНЫХ»

На английском языке

First printing 1977

Printed in the Union of Soviet Socialist Republics

$O\,\dfrac{20901\text{-}506}{014(01)\text{-}77}\;85-77$

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"It is becoming increasingly important for mankind to combat the danger inherent in the growing deterioration of natural conditions, the poisoning of the air, rivers and seas, and the pollution of cities.

"We, the representatives of the Soviet people, call on the nations of the world, on people everywhere, regardless of their nationality, religion or colour, to join together to solve these urgent problems."

(From the appeal "To the Nations of the World", adopted on December 22, 1972 at the joint session of the CPSU Central Committee and the Supreme Soviets of the USSR and Russian Federation on the occasion of the 50th anniversary of the Union of Soviet Socialist Republics.)

OUR HOME, THE PLANET EARTH

Academician Pyotr KAPITSA

In the twentieth century there are a number of problems which cannot be solved by a single country: they have to be tackled on a global basis. Man's interrelation with nature is one such problem.

One can distinguish three main aspects of the man-nature problem: firstly, the technological and economic aspect related to the progressive depletion of the earth's natural resources; secondly, the ecological aspect concerning the environmental pollution and disturbance of the biological balance; thirdly, the social and political aspect, since these problems are to be tackled by the efforts of many, if not all countries, of the world.

It has long been known that the quantitative indices which characterise, for instance, the dynamics of population processes follow a geometrical progression and are expressed mathematically in time by an exponential function. Eventually the time comes when the process acquires such an acceleration that it assumes the nature of an explosion. Today the earth's population is estimated at 3,700 million people. If it continues to grow at the same rate (on average by 2 per cent per year) as it has done in the present century, then, given all other conditions unchanged, there will be one person for each square metre of the earth's surface in 700 years time. This is, of course, an extreme case, but we have to face up to the existing trend.

Today scientists and statisticians are beginning to make a comprehensive study of the population problem, particularly its quantitative side. For this purpose wide use is made of up-to-date global statistics and computer techniques. Here of great interest are the results of the research made by J.W. Forrester and D.H. and D.L. Meadows. From their arguments come the far-reaching conclusions that "explosive nature" is inherent not only in

population increase, that the growth in consumption of electrical energy and mineral resources, and in environmental pollution are also exponential processes capable of resulting in an explosion in the very near future.

One of the principal global problems is that of energy. Man's use of energy resources is one of the factors determining the level of modern civilisation and the well-being of mankind. At present coal is the largest energy resource. If its consumption stays at the present level, there will be sufficient reserves for approximately one thousand years. If the size of the earth's population does not increase, but the rate of growth of energy consumption per head of the population remains the same as in the past hundred years, then coal reserves will be exhausted in between 100 and 150 years time. The situation with other raw materials is even more serious. Some authors have estimated, for example, that reserves of silver will be used up in the next 13 to 40 years, and those of lead in 20 to 60 years time.

With the resourcefulness of modern science, however, one need not be too pessimistic about these figures. There is a way out of the difficulty. The energy problem can be solved by using controlled thermonuclear processes. Deuterium—a heavy isotope of hydrogen—serves as a source of energy for these processes. The reserves of this isotope in the ocean may be regarded as unlimited.

Man may be able to avert the global crisis which would be sparked off by the depletion of raw material resources by switching industrial production to so-called closed-cycle processes. A similar cycle of matter can be found in nature; everything is reused and nothing is thrown away. From the scientific point of view the closed-cycle technology is quite feasible, although it is considerably more complex than today's industrial systems. A switchover to closed-cycle technology would, however, involve much greater consumption of energy. That is why it can be developed on a worldwide scale only when we have a virtually inexhaustible source of energy. Thermonuclear energy is the only source of this kind available to man at present.

The depletion of some important raw materials is already threatening the present generation. An urgent solution must therefore be found to the problems associated with the technological and economic aspect of the man-nature problem. But here the social and political aspect immediately comes to the fore: in view of their global nature these problems can only be

solved by broad international cooperation on the basis of peaceful coexistence between states with different social systems.

The ecological aspect of the problem has arisen from the disturbance of the balance in nature as a result of pollution of the environment, also on a worldwide scale. The ecological questions are not so far as serious as the depletion of raw material resources. But the effects of the environmental pollution are more dramatic. People experience them more intensely, which is why many national and international institutions and organisations are now focusing their attention on them.

The scale of modern technology cannot but disturb the ecological processes which have taken place on the earth. Industrial effluents and wastes have begun to change our environment—the air, the water and the soil—to such an extent that this presents a serious threat to the flora and fauna essential for man's existence. The task is to find those conditions of biological balance in which nature can develop in accord with the needs of human culture. This is one of the principal tasks facing the science of ecology which has so far confined itself to the study of existing processes in nature formed in the course of evolution. Ecology is undoubtedly becoming one of the fundamental sciences.

Lake Baikal may be taken as an example of the search in question. Industry needs fresh water and Lake Baikal contains a tremendous amount of it. But the lake is even more valuable by virtue of the fact that it acts as a vast biofilter producing pure water. The water in the rivers which empty into it is much more polluted than that which flows from it. This purification is brought about by biological processes. If pure distilled water entered the lake, the life in it would die out and Baikal would cease to process the polluted water which flowed into it.

The main significance of Lake Baikal for industry lies in the fact that it serves as a giant water purifier—a property which it is our job to preserve. The slogan "Hands Off Baikal" is therefore incorrect. This unique lake can and should be exploited, but in such a way as to conserve its purificative properties without disturbing the life in it. For biologists the task of using Lake Baikal in a rational way involves understanding the ecological processes which take place when industrial waste enters it and knowing precisely how and to what extent it is permissible to release waste into the lake so that it can still process the incoming pollutants. Chemists have the parallel task of developing technological

processes whose wastes will comply with the requirements of biologists, that is be such that Lake Baikal is able to process them.

It is known, for example, that the efficiency of biological processes in water depends to a considerable extent on the amount of oxygen dissolved in it. Thus in those areas where pollutants flow into the lake, one can increase the intensity of the biological processes by saturating the water with oxygen, that is aerating it, as is normally done in an aquarium. Modern technology enables us to stimulate life processes. Nature should be cured of its ills in the same way as people. If the right answer is found to the problem, the purifying efficiency of Lake Baikal may even increase.

The job of developing general principles and organising this work in the Soviet Union rests with the State Planning Commission (Gosplan) and the USSR Academy of Sciences. In a socialist system the state can fully guarantee the coordination between science and industry needed to utilise such natural features as Lake Baikal in the right way.

The Great Lakes in the USA and Canada provide a striking illustration of what happens to lakes when their waters are used indiscriminately without regard for the biological processes taking place in them. These lakes have been polluted by industrial effluents to such an extent that life in them no longer exists. Moreover their water has become unsuitable for use in certain industrial processes. Now the US government has taken a decision to restore normal life in these lakes. But for this they must reorganise completely the methods of using their water and recreate the ecological process needed to resurrect the extinct life in them. The US government has earmarked some 5,000 million dollars to be used for this purpose over the next few years. This is thought to be insufficient, however. Some experts contend that up to 25,000 million dollars will be required.

The third aspect of the problem is the creation of the social conditions in which man may implement the technologies and industries elaborated through a scientific approach to ensure a balanced development of civilisation free from the danger of "explosive" catastrophes.

As we have shown, it is possible to plan the scientific questions which must be solved in the fields of energy, technology and ecology so as to avert the dangers linked with depletion of raw materials and environment pollution. Thus, no fundamental difficulties present themselves in the first two aspects of the man-

nature problem. There is every reason to think that science will find the answer to the questions before it.

The global implementation of measures which are useful and necessary for mankind as a whole may quite often come into conflict with the social systems of different countries or narrowly viewed national interests. The solution to these problems is still in the embryonic stage, but it is a matter of urgent necessity that progress be made here too.

Let us consider a hypothetical example. A country manufactures a product without polluting its water. In the neighbouring country manufacture of the same product brings with it pollution. Manufacturing costs will be higher in the first country than in the second. It is obvious that a clean ocean full of marine life is essential for all countries and the preservation of its purity is an international requirement. The task consequently arises of prompting the country which pollutes the water to employ a more expensive technological process, although this goes against the interests of the dominating forces in its economy: in manufacturing expensive goods, it may lose the market, moreover it has to invest the capital on new equipment.

So far no effective methods have been found of exerting international influence to prevent categorically environmental pollution. To this day, for example, some countries carry out nuclear tests in the atmosphere and so poison it with radioactive substances. An authoritative international organisation will obviously have to be set up to exercise effective control of nature conservation and other measures needed to secure the prosperity of the planet as a whole.

The socio-political aspect of the man-nature problem is now becoming the subject of widespread discussion. Even in the West a number of scientists consider that technological and economic problems of global proportions can only be solved on the basis of socialist organisation of economy. This is the conclusion of the leading Dutch economist Sicco Mansholt. Representatives of other schools hold that capitalist organisations also have the latent potential for self-regulation through change in prices and taxes and that global problems of nature protection may be solved in a similar way. C. Kaysen, an economics professor at Harvard University, is one of the men who adheres to this view. His arguments, however, like many others in the same vein, tend to be abstract.

There is no doubt that socialist organisation of the economy serves as a reliable basis for the implementation of global measures on nature conservation. It is clear that the Soviet Union is already capable of resolving major ecological problems. This is why the example of the cautious, rational use of Lake Baikal's waters is of great international significance. It dramatically proves that we can use natural resources without disturbing the balance in nature—something which capitalist countries have not been able to do. In contrast to capitalism socialism by its very nature is better equipped to resolve ecological problems of this kind.

The need for international concern for the ecological well-being of the planet should promote the realisation of the principles of peaceful coexistence between states with different social systems and the gradual achievement of general disarmament. People are beginning to feel that the planet Earth is their common home and that the whole of mankind is faced with the common task of averting the ecological crisis.

There is rapidly growing interest in global problems. In their discussion there are inevitably many contradictions in the assessment of both their size and proposed methods of their solution. But more and more people agree on one thing: these problems are now extremely important for man, and the efforts of all countries should be directed towards solving them.

We have only a comparatively short time—in any event less than a century—in which to avert the ecological crisis. Scientists will have a vital role to play in this work. They were the first to give a quantitative assessment of the significance of a possible crisis and they can make a major contribution in the search for ways to prevent the crises threatening civilisation. It is the duty of scientists working in all the fields of natural science and the humanities to help the very broadest sections of the population realise the significance and possible consequences of this threat so that they might pull together to resolve the ecological problems in the whole world whose dimensions are, as has now become clear, quite small.

TECHNOLOGICAL PROGRESS AND PROTECTION OF THE BIOSPHERE

Academician Alexander VINOGRADOV

The biosphere is the thin envelope of our planet which includes the fringe zones of the atmosphere, the hydrosphere and the lithosphere and is occupied by "living matter", i.e., all the organisms inhabiting the earth. As a result of the interaction of organisms with each other and with the environment associations of organisms—biogeocoenoses, or complex ecological systems—are formed. In these ecosystems energy is transferred in a cascading fashion from one level of the ecosystem to another, thus maintaining the biological cycle of matter. Independent of man's influence these associations of organisms or ecosystems evolve under the impact of natural factors: competition between species, the destruction of links in the food chains, etc.; in other words they are dynamic systems.

The process of photosynthesis comprises the starting point of this cycle. Green plants absorb carbon dioxide, water and minerals and with the aid of sunlight form carbohydrates and numerous other organic substances essential for the growth and development of plants. At the same time free oxygen is given off in the process of photosynthesis; photosynthesis alone has maintained oxygen content in the atmosphere for a period of about 2,000 million years. As we now know, this photosynthetic oxygen is formed from the oxygen of water and not from carbon dioxide's oxygen, as has been the generally accepted view for the last hundred years. Science is, it seems, on the verge of completely unravelling the mechanism of this unique process; this will in future provide new opportunities to move along the path of progress. Thanks to this process some $1 \cdot 10^{11}$ tons of organic matter are formed each year and about the same quantity of free oxygen evolved by plants. The primary production of green vegetative organisms their biomass, in turn, gives birth to the secondary production—animals, and, eventually,

the food of man. Thus outside the field of human activity the biosphere was organised, on a kind of "waste-production" principle—the products of the life activity of some organisms being essential for the existence of others. Everything is utilised in the great biological cycle of the biosphere.

The twentieth century has dealt a blow at the biosphere. Technological progress brought fundamentally different routes of matter and energy transfer in the biosphere which disturbed the balance of nature. As a result of the brilliant advances in all fields of knowledge entirely new kinds of industrial production have emerged before our eyes; these include developments in engineering, the car and aircraft industries, atomic energy, electronics, hydropower construction, the chemical and medical industries, production of synthetic materials, not to mention the development of old industries.

The production of electrical energy in the world now doubles every 7-10 years. According to Western economists industrial production has doubled during the last 35 years and is continuing to grow; agricultural production has also doubled during the same period.

If one adds to this the tremendous environmental changes which man has caused on the earth's surface through the excavation of rocks and minerals, the building of canals and reservoirs, the control of rivers, etc., which have assumed the proportions of geological processes, then the scientific and technological progress of the first two-thirds of this century appears quite fantastic against the background of man's previous activity.

Until recently, however, people paid no attention to the long-term consequences of their activity. Industry, agriculture and the numerous cities which appeared released quite freely into the environment their gaseous, liquid and solid wastes. In the USA, for example, the amount of substances released onto the surface of the earth, into bodies of water and the atmosphere has now reached 180 million tons per year. There are some 600,000 different chemical substances in the wastes released into the environment and many of them accumulate in it. Air-polluted cities, smog, disease and poisoning from nitrogen oxides, sulphur dioxide and other industrial gases have caused considerable disquiet. It has been found that the majority of rivers and lakes in the USA, Western Europe and other regions are polluted by ecologically harmful substances to an alarming extent. Shortages of water are

now being felt due to the tremendous consumption of natural water by industry, agriculture and for domestic purposes. In a number of production processes some 500-600 tons of pure water are required per ton of production. In the USSR, for example, it is expected that in 1990 water consumption will be over 500 cubic kilometres, about half of this quantity being expended irretrievably. Under these conditions there may be a reduction in the inflow of water in the country's inland seas, which could have serious and untoward consequences.

It has been observed that aquatic organisms and fish have died out in lakes, ponds and rivers in various parts of the world. This has been caused primarily by pollution by industrial effluents containing compounds of mercury, lead, cadmium and other metals well known as strong biological poisons. Mercury, for example, has been found in large concentrations in fish and other organisms in the Baltic Sea and other bodies of water. Systematic investigations on the spread of mercury in fresh and salt water, and in their flora and fauna have shown that up to 5,000 tons of mercury enter seawater each year in industrial wastes, i.e., almost the same quantity which finds its way into the sea through natural processes. Similar results have been obtained from research on the spread of cadmium, lead and other toxic inorganic compounds in bodies of water. It should also be noted that up to one-third of fertilisers and other chemicals applied to the soil is washed away into shallow waters, ponds and lakes and eventually finds its way into inland seas and coastal waters.

The greatest ecological damage is caused by the numerous toxic organic compounds used in the fight against pests in agriculture. In this connection it is interesting to examine the fate of the well known insecticide DDT (dichlorodiphenyltrichloroethane). It played an exceptionally useful role in countering harmful insects and was used to great effect in almost every country. Only 25 years after it was first used on a wide scale did scientists discover the harmful influence of DDT on all living organisms.

Over a period of 25 years about 1.5 million tons of DDT were dispersed over the earth's surface . As has now become clear, it is very slow to break down or to be oxidised and today some two-thirds of this amount still remains on the earth's surface. DDT was found in the liver of penguins—a revelation which surprised everyone. Then it was found in soil, plants, water, berries, fruits, etc. All organisms are adversely affected by DDT which can kill

birds and small animals. It has even been discovered in mothers' milk. Like other organic substances DDT is washed out of the soil into lakes and seas. As a result plankton, fish, birds and people who avail themselves of the sea's gifts accumulate DDT. In the course of the numerous experiments performed with plants and animals it was found that DDT is only slightly soluble in connective tissue, especially adipose tissue. DDT oxidises slowly in air. It is likely that many other substances which industry and agriculture release into the environment work in a similar way to DDT.

The net result of all this was that side by side with the considerable increase of the earth's population, the growth of industrial and agricultural production and scientific and technological progress there developed another process which adversely affected the state of the biosphere—the other face of our civilisation. It may be said that the hand of man has brought about considerable changes in the biosphere—changes which were not always justified.

Many substances of industrial, agricultural and domestic origin were not used by organisms and took no part in the biological cycle of the biosphere, or at any rate they were present there for a long time without decomposing or oxidising. They were outside the natural cycle of matter in the biosphere. As a result the biosphere lost its capacity for self-purification, and could not cope with the alien load which man threw into it. For the first time in many thousands of years man came into a major conflict with the biosphere. It was this that gripped the attention of people all over the world.

On the continents the harmful influence of industrial and other wastes is more or less localised, although they affect considerable areas such as river basins, cities, inland seas and coastal waters and tend to produce a global effect. Pollution of the atmosphere has, however, already attained global proportions.

First we should recall the accumulation of carbon dioxide in the atmosphere. Its concentration is approximately 0.03 per cent which means that the atmosphere contains some $2.3 \cdot 10^{12}$ tons of it. Carbon dioxide in the atmosphere originates from volcanic gases, sources of heat, the respiration of man, animals and plants, and the combustion by man of mineral fuels. The latter process now sends at least $1 \cdot 10^{10}$ tons of carbon dioxide into the atmosphere each year.

The atmosphere exchanges carbon dioxide with the ocean in

quite an intensive fashion: approximatley $1 \cdot 10^{11}$ tons of carbon dioxide are constantly in a state of interchange between the atmosphere and the ocean. The upper layers of the ocean exchange carbon dioxide over a period of between 5 and 25 years, while the deep layers require between 200 and 1000 years. Complete interchange of the carbon dioxide in the atmosphere takes place over a period of 300 to 500 years. The ocean contains 60 times as much carbon dioxide ($1.3 \cdot 10^{14}$ tons) as the atmosphere. Because carbon dioxide dissolves more readily in cold water, i.e., in high latitudes, the ocean acts as pump which mostly absorbs carbon dioxide in cold areas of the ocean and blows it out into the atmosphere in the tropics. The pressure of carbon dioxide is therefore slightly higher in the tropics than in higher latitudes. In the tropics compounds of carbon dioxide such as calcium bicarbonate are decomposed by organisms. Calcium carbonate enters the skeletons of organisms from which atolls are later formed in tropical waters. Here it should be stressed that as a result of this global mechanism the predominant processes in the biosphere are those which tend to exhaust carbon dioxide from the atmosphere. We need only recall that up to $2 \cdot 10$ tons of carbon dioxide are stored up in the form of solid calcium carbonate in the earth's crust. If what we say below on the behaviour of carbon dioxide is confirmed, then this means that the biosphere does not function and its mechanism has broken.

Systematic observations of the amount of carbon dioxide in the atmosphere begun on the Hawaiian Islands in the middle of this century have shown that its concentration has increased in recent years from 0.031 to 0.0324 per cent. More accurate measurements made over the last ten years show that there is an annual increase of 0.2 per cent which has been attributed to the activity of man. Meanwhile it is well known that carbon dioxide works like a hothouse glass: it lets in the sunlight and retains infrared (heat) radiation, thus producing the "hothouse effect", which takes place on Venus. In the past scientists contended that the carbon dioxide in the atmosphere regulated the temperature of the earth. Many researchers have calculated that at the present rate of increase of carbon dioxide its concentration in the atmosphere will grow by 20 per cent between 1973 and the year 2000; in other words it will rise to 0.0379 per cent which in turn may bring about a global increase in temperature with all the ensuing consequences such as melting of ice, etc.

It should be pointed out, however, that the increase in temperature on the earth observed in the period between 1900 and 1945 (0.6° C), was followed by a slight decrease, which is continuing today. At the same time the concentration of carbon dioxide in the atmosphere is growing steadily. Many new scientific questions have arisen which require that a profound study be made of the link between carbon dioxide and the most diverse processes on the earth. Let us take one of them as an example. Since numerous laboratory experiments have shown that the optimum concentration at which plants assimilate carbon dioxide is at least one order higher than its concentration in the atmosphere (in these experiments the production of organic matter also grew), there is no explanation for the fact that plants are now starving and not drawing carbon dioxide from the atmosphere to its previous level. Is this a little-noticed effect? It is thought that green plants take from the atmosphere over 160,000 million tons of carbon dioxide, yet its concentration in the atmosphere is growing.

Dust pollution of the atmosphere has a more complex global influence. Change in the transparency of the atmosphere causes the intensity of solar radiation to change. There are various sources of dust: sand dispersed from the deserts of arid regions whose area is growing because of deforestation, erosion and degradation of soils; volcanic eruptions (formation of ash); emissions of dust together with gases from factories; treatment of agricultural land with chemicals (dispersion of fertilisers and pesticides from aircraft); forest fires; atomic explosions, in which the dispersed substance is thrown even into the stratosphere. We may also recall that every year at least $1 \cdot 10^4$ tons of cosmic dust fall on the earth. We know from observations that the products of nuclear explosions and volcanic ash travel round the earth several times in but a few days. So there is no wonder that smoke and sulphur dioxide spread from the Ruhr to Scandinavia.

Particles of dust several microns in diameter normally remain in the atmosphere for anything from a few days to a few weeks. Radioactive dust stays in the stratosphere for several years. Numerous observations have shown that in recent years the level of dust in the air in many cities has grown dozens of times and in the world at large is 20 per cent higher than at the beginning of the present century. The amount of dust which rises each year into the air totals many millions of tons. If dust settles directly on the ice of mountainous regions of the poles this may cause partial melting

due to the fact that the fine layer of "black" dust absorbs solar radiation. The accumulation of dust in the atmosphere creates, as it were, a screen for solar radiation and changes the albedo of the earth. The albedoes of the surface of land, ice and bodies of water are, of course, very different. Cloud cover, for example, of 5 per cent of the earth's surface, results in a temperature change of several degrees, which in turn, may produce glaciation conditions provided there is constant and intense dust pollution.

Here we can risk drawing a comparison between the earth polluted in such a way by dust and Mars. Perhaps dust pollution of the atmosphere somehow compensates for the influence of the increased concentration of carbon dioxide in the atmosphere. But this is only a possibility. In the past scientists tried to link glaciation (ice ages) with the activity of volcanoes which threw out ash. But it should be remembered that when a volcano is active it spews out ash and carbon dioxide simultaneously.

People are becoming anxious about oxygen. Indeed the consumption of oxygen in industry is growing at a phenomenal rate. In a transatlantic flight an aeroplane burns from 50 to 100 tons of oxygen. In the USA some 100 million motor vehicles consume twice as much oxygen as is created in that region. A similar picture appears in the FRG and some other countries. Estimates show that there is no immediate danger, but the oxygen balance in the biosphere needs careful study.

Another problem causing some concern is the destruction of the ozone layer in the lower stratosphere due to the action of supersonic aircraft. Their engines release lower oxides of nitrogen which are oxidised and thus destroy the ozone. According to some calculations, if 50 per cent of the ozone layer were destroyed, this would increase the dose of ultraviolet radiation by a factor of 10 and cause people and animals to go blind.

Scientists are also concerned about the thermal pollution of the biosphere, i.e., the effect of the man-made heat produced by machine industry, power stations, various devices combusting mineral fuel, etc. As has already been mentioned, warm water released by industrial enterprises into bodies of water is conducive to the development of flora: there is rapid flowering of blue-green algae, especially if the water contains nutritive substances such as compounds of phosphorus, nitrogen, etc. The amount of heat which is produced in small, but heavily industrialised states may be approaching the quantity they receive from the sun.

Finally, let us examine those pollution processes taking place in the ocean which are tending to assume global proportions, and specifically the oil spills into the ocean water. Oil spilled into the ocean spreads across the surface forming a thin film. This disturbs the exchange of gases between the water and the atmosphere and thereby disturbs the life of plankton which produces oxygen and which is the primary organic matter in the ocean. In recent years about $4 \cdot 10^6$ tons of oil, or about 0.1 per cent of all the oil produced on the continental shelves have found their way into the ocean as a result of various accidents. Large-scale offshore production of oil (at present it accounts for 20 per cent of total world oil production) followed its discovery in continental shelves. There will undoubtedly be intensive development in this area.

What has been said is probably sufficient to show the extent of the danger that now faces present and future generations. There is no doubt that a close link exists between population growth, industrial and agricultural production, urbanisation, the use of the biosphere's resources and its pollution.

In the twentieth century care for people's welfare is an integral part of the concept of "technological progress". Conservation of nature and nature reserves has been going on for a long time. It has been carried out mainly on a facultative basis. Today this approach is still essential, but not sufficient on its own. An active form of protecting the biosphere is called for.

The fundamental question arises: what are we to do with the growing amount of ecologically harmful wastes of industry, agriculture and other spheres of man's activity?

There are many approaches to this question. For instance, one could isolate the harmful wastes and bury the most dangerous of them in disused pits, deep wells, or other "pockets" of the lithosphere. But in this way pollution will be introduced into the lithosphere and probably to the same extent as on the surface of the earth. On the other hand, this would necessitate geological prospecting for appropriate territories and rock strata where there is no movement of underground waters, etc. In addition wastes might be disposed in a form providing for their biological or mineral decomposition or complete oxidation and thus participate in the biosphere's general cycle of matter.

However a fundamental solution to the problem of eliminating pollution of rivers, other bodies of water and the atmosphere by wastes from industrial and other enterprises lies in the planning of

new enterprises and, where possible, the switchover of existing ones to a closed-cycle technology in which there would be no release of ecologically harmful substances into the environment and the minimum quantity of fresh water would be used, in other words, the organisation of low-waste or wasteless, closed-cycle production processes. This would not necessitate the construction of special, expensive purification installations. But it would naturally demand the development of new technologies, that is a review of existing technological regulations. This would require a great deal of time, but no one believes that the battle for pure natural waters, the atmosphere and man's environment is a short-term affair. Many scientific institutes would be drawn into this work, since the problems themselves are of an extremely complex nature.

The institutes of the USSR Academy of Sciences are faced with a number of important problems:

—development of the fundamental principles of nature use, assessment and forecasts of the state of the environment;

—forecasting of regional and global changes arising in the environment as the result of natural processes and man's activity;

—development of rational means of using, protecting and reproducing the biological resources of the biosphere, study of the impact of man's activity and the pollution he causes on the biological resources of the earth and the emergence of ecological problems;

— study of the effect of man's activity on the atmosphere;

—development of the scientific principles for new technological processes which will have no harmful influence on the environment;

—development of mathematical models to solve the problems of optimum management of the biosphere and individual ecosystems;

—development of the principles of ecological and economic assessment of the use of the most important natural resources and assessment of the damage caused by man's activity;

—development of the scientific principles for a unified system of law standards in the field of nature use.

In conclusion let us dwell on the organisational aspect of protection of the biosphere both in the USSR and internationally.

Ten years ago this problem was of interest only to scientists. Soon in the West the problem of pollution of the biosphere became particularly acute. So apart from the expansion of research work the need arose for state administrative institutions in the form of

committees and ministries. Such major international organisations as UNESCO and FAO adopted special programs on the man and nature problem. Under the weight of world public opinion UN held an international conference in Stockholm in June 1972 devoted to environmental problems.

The state and public organisations in the Soviet Union have been giving the problem of the environment their serious attention for a long time. Particularly intensive measures have been taken in recent years. In September, 1972, a session of the Supreme Soviet heard a report on the environmental pollution control in the USSR. At the end of 1972 the Central Committee of the CPSU and the Council of Ministers of the USSR adopted a Decree "On Intensification of Nature Conservation and Improved Utilisation of Natural Resources". In accordance with this Decree the State Committee of the USSR Council of Ministers for Science and Technology and the USSR Academy of Sciences organised the Inter-Departmental Scientific and Technological Council on Comprehensive Problems of the Environment and the Rational Use of Natural Resources.

The USSR carries out joint research on the protection of the biosphere with other members of the Council for Mutual Economic Assistance. In 1972 the USSR-USA Agreement on Cooperation in the Field of Environmental Protection was signed. Cooperation in this field is developing with a number of other countries both on a bilateral and multilateral basis. Thus the work to protect the biosphere is becoming increasingly international and global in its scope. There is no doubt that this socio-economic problem will be solved by mankind striving as it is for peace and cooperation.

MAN, SOCIETY AND THE GEOGRAPHICAL ENVIRONMENT

Academician Innokenty GERASIMOV

In the broadest sense the interaction between man, society and the environment may be regarded as the use by society of all possible natural resources for material production (i.e., production of energy, raw material, agricultural production, etc.) and for guaranteeing the viability of man himself (i.e., the natural conditions for his existence). The fact that man and society come into contact with nature on so many fronts determines the diverse influence which the environment has on social activity, and the physical and moral state of each individual.

The problem of the interaction between nature and society has an important place in the thinking of various eras, starting with the age of classical philosophy. However, the pre-Marxist doctrines lacked the foundation necessary for a genuinely scientific analysis of this problem. By foundation we mean a complete understanding of the objective laws of development of society and the role of the natural environment in this development. Only Marxist-Leninist theory and methodology of scientific analysis were able to reveal the objective laws of the multifarious processes of interaction between nature and society in the general evolution of mankind and the change of the basic social formations.

According to the propositions of Marxism the process of labour, which forms the basis of interrelations between man and his natural environment, determined the origin of society with its special laws of formation and development. "Labour is, in the first place", wrote Marx, "a process in which both man and Nature participate, and in which man of his own accord starts, regulates, and controls the material re-actions between himself and Nature."[1]

People's working activity, i.e., the basis of the existence and

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[1] K. Marx, *Capital*, Vol. 1, Moscow, 1974, p. 173

development of society, is a social category. So in their interrelations with nature people act within the bounds of specific social relations. "In order to produce", wrote Marx, "they enter into definite connections and relations with one another and only within these social connections and relations does their action on nature, does production, take place."[1]

Spontaneous use of the natural environment by man and plunder of natural resources, which appeared at an early stage of man's history, developed and expanded in the era of feudalism. But they were manifested particularly clearly during the development of capitalist society and its transition to the ultimate stage—imperialism.

In proving the spontaneous and destructive impact of capitalism on the productive forces of nature the founders of Marxism predicted with great scientific foresight the fundamental changes in interrelations between society and nature in the conditions of the new social formations of the future. In his first essay on political economy Engels wrote about that great revolution "...to which the century is moving—the reconciliation of mankind with nature and with itself."[2] In *Anti-Dühring* Engels points out that until the scientific control of the forces of nature is subordinated to the rational control of productive relations between people, these forces "...are at work in spite of us, in opposition to us, so long they master us..."[3] The position changes fundamentally in planned socialist and communist societies.

The conclusions of Marxist theory on the problem of the interaction between society and nature have not only maintained their fundamental scientific value, but acquired tremendous urgency in the present day. This is the result of many new phenomena caused both by the radical social and economic changes taking place in the world, and by the modern scientific and technological revolution. The environmental problems are at present at the focal point of world public opinion.

Recently publishers in the West have released a torrent of scientific and popular scientific literature, and other material on the problem of man and the environment. The underlying theme in this literature is the question of so-called "ecological crises". i.e.,

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[1] K. Marx and F. Engels, *Selected Works*, Vol. I, Moscow, 1973, p. 159

[2] K. Marx and F. Engels, *Collected Works*, Vol. 3, p. 424.

[3] F. Engels, *Anti-Dühring*, Moscow, 1975, p. 320.

the rapidly growing threat to the living conditions of present and future generations inherent in the changes inflicted on nature by the hand of man. It is maintained that because of the increasing and uncontrolled use of natural resources, continual pollution of the atmosphere and hydrosphere, and the spontaneous and devastating transformation of the natural environment modern man has already experienced in different parts of the world either total depletion or a direct threat of depletion of the natural resources essential to maintain and develop productive forces. This has been accompanied by a sharp degradation of the environment and the appearance in it of properties which are dangerous or even fatal for all living things including man. At the same time the view is often expressed in the bourgeois press that this "general calamity" is more acute than all other social and political problems. The principal recommendations advanced by the ideologists of the "ecological explosion" boil down to appeals to reduce artificially the requirements of mankind (specifically by controlling population), slow down the development of technology and establish international control over the use of natural resources.

This flood of literature on the environmental problems naturally has an intense and profound influence on public opinion in different countries. For these are the questions which affect directly the interests and needs of each individual, each nation and mankind as a whole.

The protection of the natural environment is becoming not just an important problem for natural science, but a serious socio-political question around which a fierce ideological struggle is developing. For this very reason the journal of the Communist and Workers' parties *World Marxist Review* took the extremely important initiative of holding a special international symposium in March 1972 whose theme was "Marxism-Leninism and the Problems of Protecting the Environment"[1] Marxist scholars and representatives of Communist and Workers' parties from 36 countries took part in the symposium. In formulating the Marxist appraisal of the modern significance of environmental problems the participants underlined the danger of the artificial exaggeration or even premeditated distortion in modern bourgeois literature of the objective essence and scientific significance of

[1]*World Marxist Review*, No. 6, 1972.

these problems for certain political ends. The principal aim of this strategy is, by emphasising the need for general human concern for the natural resources of the earth and calling for a thrifty attitude to nature, to free capitalism and colonialism from their special responsibility for the rapacious exploitation of the natural resources both of their own countries and of the developing and dependent countries and for damaging the environment in which we live.

Soviet science has always paid great attention to the problems of protecting nature and using its resources in a rational way to develop the country's planned socialist economy. In this respect Soviet scientists work on the principle that to meet the growing demands of society nature must not only be protected, but enriched by transforming it in a purposeful way. Scientific research on these problems has greatly expanded in terms of scope and content.

It is quite clear that both the whole problem of the interaction between society and nature, and its most important aspects are of a highly interdisciplinary nature. This means that many social, natural and engineering sciences have a large part to play in tackling this problem. It is essential to expound a most general, but at the same time an integral conception of the problem under consideration.

In its most general aspect the problem of protecting the natural environment and using natural resources in a rational way has been the subject of study in this country for over a century. V. Dokuchayev and A. Voeykov were among the great Russian natural scientists who worked on the problem. After the Revolution Soviet science made a great contribution to studying natural conditions and surveying and developing the country's natural resources and carrying out a number of important measures to conserve them. In recent years constructive ideas aimed at developing scientific programs of purposeful environmental development have gained acceptance in our country.

In the course of this work fundamental questions of modern science and practice have been developed which involved theoretical analysis of the forms of interaction between human society and the natural environment. This gave the foundation for the development of the scientific principles for optimising the forms of interaction (in particular, the exchange of matter between society and nature, the reproduction of natural resources, nature

protection during its use, etc.), optimising the ways and means of improving the natural environment in the course of its purposeful transformation, analysis of ways of increasing the productivity of the biosphere and developing methods of managing its various processes. *Resources of the Biosphere on the Territory of the USSR* published in Moscow in 1971 contains an analysis made by Soviet scientists of the resources of the biosphere in the USSR and characterised the scientific principles for their rational use.

The Modern State of the Natural Environment in Europe and Ways of Conserving and Improving It published in Moscow in 1971 is another work based on an analysis of the ecological situation in Britain, the FRG, Holland, Spain, Italy, Finland, France, Sweden, Bulgaria, Hungary, the GDR, Poland, Rumania, Czechoslovakia and the USSR. It determines the initial methodological approaches on which to base future planning of research and development of practical proposals.

The scientific analysis carried out by Soviet experts in the above work led them to make the following conclusions:

European countries, which differ in terms of their geographical position, size of population and area, as well as in the level of technical and economic development and social system, have different environmental conditions. However, alongside the very considerable differences there are several important similarities, of which profound and general anthropogenic changes in the natural environment are the most important.

These changes over the territory of Europe are mainly the result of the prolonged exploitation of natural resources and the primarily spontaneous, i.e., uncontrolled, nature of this exploitation. At the same time the intensity of use of natural resources in Europe has not been uniform. The exploitation of natural resources which began in primitive society later grew unremittingly and led to today's situation, which is critical as far as certain resources are concerned, in conditions of scientific and technological progress.

One can distinguish the following principal trends in scientific and technological progress which are of decisive significance for present-day interrelations between society and the environment:

1. Expansion, growing intensification and profound change in the structure of modern industrial production. Here we should distinguish in turn the following factors as being especially important for the environment:

a) the rapid expansion of open-cast mining or the growing areas under waste piles around mines. This growth has aggravated the land problem in many industrialised regions of Europe and given rise to the task of recultivating the waste lands;

b) the high level of pollution of the air in industrial areas by gases and solid particles which necessitates increasingly wide application of various methods to combat smoke from factory chimneys;

c) excessive pollution of natural bodies of water by various industrial effluents, some of them toxic. This phenomenon has been so widespread that it has transformed many of Europe's lakes and waterways into lifeless sewage pits, whose water is unsuitable for domestic purposes.

d) release of heated water from industrial enterprises and the increased radiation of heat into the atmosphere from industrial installations have produced local heating of some industrial areas and created the threat of growing global heating of the air, which might involve profound and irreversible changes in nature as a whole.

2. Mention should be made of the new (and in some cases progressive) trends and forms of agriculture, forestry and other sectors which use natural resources. Let us single out the growing application of various fertilisers and other chemical agents (pesticides, biological stimulators, etc.). Together with the positive effect—increased productivity in agriculture, forestry and other sectors of the economy—this disturbs the natural cycles of matter and energy, produces phenomena of an anthropogenic nature in bodies of water (silting, algae overgrowth and other similar processes) and thereby affects the environment's ability to preserve and maintain its natural properties and renew used resources. In particular it is becoming increasingly difficult for natural vegetation and the wild animal species, which have adapted as the result of a prolonged period of evolution to specific environmental conditions, to exist and reproduce in sufficient quantities.

3. The rapid urbanisation, the movement of population from the country to the city and the continuous expansion of urban facilities also have a negative effect on man's living and working conditions (e. g., the poisoning of the city air and water, urban noise, unfavourable microclimatic changes, etc.).

4. The growing significance in the life of modern European society of various forms of recreation, which is the main antidote to

the negative consequences of urbanisation. So we can see in all European countries the rapid growth of mass-scale tourism (particularly car travel), which in some cases due to poor organisation and lack of recreative facilities tends to intensify society's unfavourable influence on the natural environment.

The most important trends in the environmental protection measures taken in the European *capitalist countries* are as follows:

—the growing recognition among progressive public opinion in each country of the critical environmental degradation and the growing difficulties in the use of natural resources; as a result a mass movement, oriented against anti-monopololy, is gathering momentum for conservation of nature;

—implementation under the pressure of public opinion of certain state prohibitory measures on the protection of the environment (restriction of the dumping of industrial wastes into bodies of water and reduction of smoke discharges; control of hunting and trapping, etc.);

—the development of organised (as opposed to spontaneous) recreation (national parks, protected recreation zones, etc.) and greater conservation of individual natural phenomena.

Nevertheless no capitalist country in Europe has managed to overcome the main negative consequences of society's influence on natural environment. Moreover, industrialisation and urbanisation are taking a firmer grip in all of these countries. Their populations are becoming more and more concentrated in the cities. Air and water pollution is increasing and many agricultural areas are becoming desolate. In their place appear areas for recreation and sport. This, however, takes place on a limited and selective basis and in the interests of the better-off section of the community.

Thus almost all the European capitalist countries are at present gripped in the powerful clutches of a grave historical legacy in the form of a seriously disturbed natural environment and the increasing negative influence on the environment of recent industrialisation and urbanisation.

The main trends of the diverse and intensified influence on the environment associated with progress in science and technology, which were outlined above in relation to the European capitalist countries, are also to be seen in the *socialist countries*. In all these countries consumption of natural resources and the volume of industrial waste are growing; there is a general drift of population

from the country to the city; air and water pollution is in evidence in major industrial centres, etc. At the same time these modern consequences of society's influence on nature in the socialist countries almost everywhere are added to a grave legacy of their capitalist past.

There are a number of important features peculiar to the socialist system in the measures which have been taken or projected on the conservation and improvement of the environment. The principal ones are as follows:

—systematic state control over all forms of environmental pollution by industrial and domestic wastes and implementation of strict and planned measures to limit and eliminate them by introducing new forms of industrial technology; an actual example of these measures in the USSR is the Decision adopted by the CPSU Central Committee and the USSR Council of Ministers "On Measures to Prevent Pollution of the Volga and Ural River Basins by Untreated Sewage";

—rapid progress as regards the principles and methods involved in planned construction of new cities and modernisation of existing ones to create the most favourable conditions for public and private life and the recreation of the entire urban population, and eliminating all the negative consequences of modern urbanisation; the General Plan for the Reconstruction and Development of Moscow exemplifies the application of these principles in the USSR;

—scientific and technological elaboration and planned implementation of environmental development programs over large areas for the purpose of using and reproducing natural resources, and conserving and improving the natural environment; the Soviet Government resolutions on the rational development of the natural resources of Lake Baikal and the conservation of its unique properties serve as an example of such programs;

—a social policy in developing recreational areas with the aim to ensure their wide use by the entire working population;

—implementation on a scientific basis of various state measures to conserve and expand nature reserves and protect and enrich their flora and fauna.

The resolutions of the 24th and 25th Congresses of the CPSU regard the solution of these problems as one of the preconditions for the construction of the material basis of communist society in the Soviet Union.

Environmental protection and the rational use of natural resources comprise one of the sections of the one-year and five-year state economic development plans of the USSR, which lay down the specific tasks to be fulfilled in these two areas.

In the Soviet Union's tenth five-year plan a new, extensive program of measures will be developed and implemented on the environmental protection. The "Guidelines for the Development of the National Economy of the USSR for 1976-80" passed by the 25th Congress of the CPSU envisage the following measures:

To study natural resources and monitor the state of the environment and the sources of its pollution by means of up-to-date scientific and technological facilities.

To introduce new effective techniques and systems of developing the deposits of mineral resources, advanced technological processes for their mining, upgrading and processing, with a view to increasing the degree of mineral extraction, ensuring a fuller and more comprehensive processing of mineral resources and also drastically reducing the harmful effects of waste products on the environment. To take further steps to devise and introduce technological processes which reduce the amount of waste and ensure its maximum utilisation as well as water recycling systems.

To develop specialised production of machinery and equipment for the installation of high-efficiency purification plants at industrial enterprises.

To devise new ways and means of combatting harmful discharges into the atmosphere, industrial, transport and other noise, vibrations and effects of electric and magnetic fields and radiation.

To increase the fertility of the soil and improve its protection from the harmful effects of water and wind erosion, resalination, aridisation, underflood and pollution by industrial waste. To take a thrifty approach in the allocation of agricultural lands for other uses. To ensure recultivation of land after mining and peat-digging.

To take steps towards a comprehensive and rationalised utilisation and conservation of water and forest resources.

To improve the techniques of forecasting the effects of production on the environment and take into account its possible consequences in project planning and decision making.

The results of the research carried out by Soviet scientists provide a basis for the following general scientific conclusions of theoretical significance:

Modern man as a whole is in fact faced with rapid deterioration of the ecological conditions which sustain him, more intensive development of spontaneous natural processes of a destructive kind and growing difficulties in the further use of natural resources. As a result the problems of effective use of natural resources, warning and prevention of destructive natural phenomena, and rational conservation and planned improvement of the environment have now acquired great significance for the whole of mankind.

The natural environment and its resources should today be regarded as priceless *public (social) property* which requires special consideration and the systematic implementation of the purposeful and coordinated measures needed to guarantee a prosperous future both for the population of individual countries and mankind as a whole, primarily in regard to ecological conditions. The fact that in the capitalist world natural resources can be privately owned clearly runs contrary to the modern situation as regards the environment and should belong to the past.

The current scientific and technological revolution is having a conflicting influence on the state of the environment. On the one hand, the growing might of technology and the increased production of materials and energy intensify the various "pressures" which man exerts on the environment. On the other, advances in science and technology enable us to derive the benefit from new substances and forces of nature, satisfy peoples' many requirements more fully, and give us the means to improve our environment.

This latter aim which is often called *the purposeful development of the environment*, should now come increasingly to the fore. Essentially its general task is to ensure the qualities of the environment needed to support human life under the conditions that are constantly and irrevocably changing due to the influence of scientific and technological progress. Most important among these qualities are the continuous intensification of many natural processes which take place in the environment (e.g., biological productivity) and ensure its use for many different purposes and the acquisition by the environment of new properties to raise the standard of life of modern human society.

Mankind can not only predict and avert a future degradation of the environment, but ensure its purposeful improvement. As we have already said, this was the contention of the founders of Marxism and it has been confirmed by the whole historical

development of interrelations between society and nature at various stages, including the present one. Marxism has always rejected the old and new Malthusian theories that by virtue of their limited quantities natural resources cannot guarantee the material requirements of the world's growing population. It is an undeniable fact that the constant progress of scientific and technological methods of developing and using natural resources is outstripping the general growth in society's need for them. The modern scientific and technological revolution provides a great deal of evidence to support this. At the same time the classic Marxist writers pointed out with tremendous insight that the environment would be increasingly devastated by the spontaneous use of its natural resources in the conditions of capitalism. They predicted a radical change in interrelations between society and nature under socialism.

The capitalist system with its private ownership of the means of production and spontaneous exploitation of natural resources in the interests of the ruling class (and the conversion of entire countries and regions of the world into raw material adjuncts of the imperialist countries) bears direct responsibility for the deterioration of the environment throughout the world. The very fact that firms and monopoly organisations vie with each other for economic advantages at the expense of the working population and the peoples of the dependent and exploited countries renders capitalism as a whole incapable of finding a radical solution to the problems of protecting and improving the environment in full measure in the interests of mankind and future generations. This does not detract, however, from the value of certain state measures which have been taken as a result of progressive people's struggle in capitalist countries for conservation and improvement of the environment nor from the value of the research done there.

The highest aims of creating a socialist and communist society, which are to satisfy to the full the material and cultural requirements of all members of society bearing in mind the needs of future generations, produce in this society a completely different attitude to the natural environment. The establishment of a socialist system removes private ownership of the principal means of production, including all kinds of natural resources. The land, the earth's crust, forests, the vegetation, the animal world and other natural resources all become public property in their entirety. They are used in a planned and purposeful way on the basis of

scientifically-grounded state economic plans in the interests of society as a whole. All this creates fundamentally new social preconditions for the implementation of a single, internally coordinated national policy on the use of natural resources and the conservation and improvement of the natural environment.

This socialist policy is aimed at:

—a complete halt to pollution of the air and water by substances which are harmful or unfavourable for the life of man; this is to be achieved by developing and introducing the appropriate technology and exercising strict control over the application of chemical weed-killers and pest-killers and other substances used in agriculture, forestry and other sectors of the economy which cause profound disturbances in the flow of natural processes and prevent conscious control of them;

—creation of favourable living conditions for the entire population of towns and other human settlements by means of scientifically-based urban construction and regional planning and elimination of all the negative consequences of urbanisation;

—rational use of all natural resources with guaranteed natural increase in the reproduction of renewable resources and strictly calculated consumption of non-renewable ones;

—purposeful development of natural conditions over large territories (control of river flow and transfer of water between river basins, drainage and irrigation, field-protective and water-retaining afforestation, creation of national parks, etc.) to ensure effective and all-round use of natural resources, combat natural calamities and improve working and recreation conditions;

—conservation of all gene pools of living nature formed in the process of evolution in all the main natural ecological systems as a basis for raising new races of cultured plants and carrying out scientific research on the protection and increase of biological productivity of our environment.

At the present stage of development of science and technology it is possible to avert the danger of progressive deterioration of the natural environment on a worldwide scale. Peaceful coexistence, widespread international cooperation on an equal footing, development of the national economies of all countries, broad exchange of scientific and technological experience and implementation of agreed international measures will help to guarantee effective and purposeful development of the environment and preserve it for the whole of mankind.

ECOLOGICAL ASPECTS OF SOCIAL PROGRESS

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Among the problems facing modern civilisation those of man's attitude to the natural environment are receiving an increasing amount of attention. Considerable changes are taking place in the nature of these problems. Twenty or thirty years ago "shortages" of various kinds were the most acute aspects and the environment was regarded mainly as a complex of required resources. Today there is a growing threat of a surplus of human pressure on nature. We are beginning to comprehend the biosphere in terms of its potential for assimilating what is produced; the problem arises of combining in the best possible way modern scientific and technological development with the objective processes taking place in the biosphere.

Besides increasing the use of natural resources and the degree of human influence on the environment scientific and technological progress increases the responsibility of society for the preservation of the natural environment and for expediency in carrying out transformations of it. The problem of society's interaction with nature is becoming increasingly pressing for engineering and science. It is also of considerable interest from the point of view of philosophy.

Criticism of the Concept of "Ecological Pessimism"

In present-day conditions the problem of man's interaction with nature is becoming the subject of wide ideological debate. In Western bourgeois literature side by side with the non-constructive line of pseudo-optimism, which strives to conceal the threat of a serious ecological crisis in the developed capitalist countries, we see serious concern expressed about the state of the environment. It is reflected in a very large number of works, such as those published

under the auspices of the so-called "Club of Rome" which was organised several years ago by the Italian economist and businessman A. Peccei to study the interaction of society and nature and the various possibilities for the future development of mankind.[1]

Of particular note in this context are *The Limits to Growth* written by a group of authors (the title page lists four members of staff of the Massachusetts Institute of Technology under Professor D. L. Meadows)[2] and *The Closing Circle*, which is the work of the well-known American biologist B. Commoner,[3] an expert in the field of ecology. These books are imbued with a feeling of alarm over the near future of mankind in the context of its interaction with the natural environment. They are of interest in that they have attempted comprehensive analysis, quantitative prediction and modelling of many aspects of the development of society in its interaction with nature.

The Limits to Growth, like J. Forrester's *World Dynamics*[4] before it, attempts to give on the basis of systems analysis a numerical calculation of the various ways in which mankind might develop in the future. Commoner makes a detailed examination of environmental pollution, mostly in the USA, shows the social and economic causes of this pollution and the other disturbances in the balance of the natural environment and puts forward some ideas on ways of restructuring the economy to optimise man's interaction with nature.

Let us concentrate our attention on the methodological side of the books! It must be said that regardless of the correctness or incorrectness of the calculations many of the propositions set forth in these works raise serious objections. *The Limits to Growth*, for example, attempts to take a systems approach to forecasting. In this approach the authors take several factors—size of population, volume of resources, level of pollution, etc., and reveal the summary effect of their impact for various possible changes in each of them. However in this approach the dynamics of each parameter

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[1] A. Peccei, "The Predicament of Mankind", *Successo*, June 1970; A. Peccei, Where Are We? Where Are We Going?", *Successo*, February 1971.

[2] D.H. Meadows, D.L. Meadows, J. Randers, W. Behrens, *The Limits to Growth*, New York, Universe Books, 1972.

[3] B. Commoner, *The Closing Circle*, J. Cape, London 1972.

[4] J. Forrester, *World Dynamics*, Wright-Allen Press Inc., Cambridge, Massachusetts, 1971.

are assumed to be independent of change in the others; a change in one of them is analysed on the supposition that the others do not change. The integral properties of the system of parameters of human society are overlooked. The authors suppose, for example, that if people could increase in a significant way the effectiveness of the use of natural resources, then this would, by removing the threat of hunger and want, cause such a sharp growth in production that the corresponding intensification of environmental pollution would create intolerable living conditions on earth.

However, real human society is not a linear system. Many parameters of its development are closely interconnected by direct and inverse links. In our view it is not acceptable to extrapolate the growth of each development parameter in isolation on the basis of current trends, and so ignore these links.

The authors believe that the main threat to mankind arises out of the depletion of natural resources and environmental pollution, which are an inevitable consequence of population growth and the even faster increase of production and consumption. At least three major objections can be raised here:

1. In considering population growth it must be noted that unlimited increase cannot serve the ends of social man. It is well known that population growth is closely linked with economic and social conditions and tends to decrease with growing prosperity and urbanisation. As the significance of such growth-limiting factors as disease and hunger decreases, an increasingly important role is played by conscious control which is determined by the interests and wishes of individual families. We do not, however, see anything impossible or intolerable in the fact that consciously developing human society will find it necessary to regulate its size (in one direction or the other) in the same way as at present it is beginning (in the socialist countries) to regulate its qualitative composition.

From a methodological point of view it is incorrect to concentrate solely on population size. Many other factors besides numerical size determine the state of the population. The obvious negative phenomenon of unemployment, which is a permanent feature in the capitalist countries, is not caused by local "population explosions", but by quite definite social and economic factors.

Even when the size of the working population more or less corresponds to the potentialities of production, a significant part

is played by its qualitative composition —the distribution of the population in different jobs and professions and according to general education level and interests, etc. The qualitative composition is the result of training of personnel in the broad sense of the word. It should obviously correspond to the tasks of future production development, which in their turn should be subordinated to the general social objective. The rational preparation of each new generation for the fulfilment of its role in production is based primarily on the long-term prospects of society's development. At the same time this preparation should include determination and development of the interests and abilities of each individual in the context of the social development trends.

Thus the control of a number of parameters which determine the state of society is in our view essential and is indeed already being carried out in socialist society.

Time will show whether "self-regulation" will be sufficient to hold the size of population at a level at which its requirements can be satisfied.

2. B. Commoner, J. Forrester and D. L. Meadows and his coauthors ascribe to the sum total of natural resources (as a measure of the potential for meeting society's demands) an initial value (for the present time) which in future will only diminish. One cannot agree with this idea. It is not acceptable to make absolute an approach to natural resources (as the source of all that man needs) from this point of view. It is essential to bear in mind that each concrete point of view both on whether a given element of the environment is a natural resource and on the means of using it changes radically, as history testifies.

The total volume of each non-renewable natural resource can, of course, only decrease. This does not mean, however, that the possibilities of satisfying the human requirements linked with it are reduced. On the contrary, in the course of scientific progress and change in the means of production these possibilities increase, both as a result of increasing the efficiency of using each natural resource and utilising new resources, and by finding fundamentally new ways of satisfying the particular human need. If this were not the case, mankind would have found itself in a blind alley a long time ago. For example, hunting as our ancestors did would not be sufficient to feed a population of considerably smaller proportions than the present-day one.

As far as renewable natural resources are concerned, apart from changing the methods of their use one should also bear in mind that it is possible to transform the whole cycle of renewal and increase the output of the resources themselves.

3. One cannot agree with the assertion that increase of pollution and other changes in the environment unfavourable to man are inevitable because of the growth of production and population.

B. Commoner has shown by examining in detail the process of rapid air, water and soil pollution in the USA in the 25 years after the war that the tremendous growth in pollution (by a factor of about 7 or 8 per head of the population) is due not to the growth of production or per capita consumption, but to changes in production and consumption (wide use of chemical fertilisers, synthetic materials, detergents, production of larger automobiles, etc.) caused by the monopolies' desire to obtain bigger profits. Social and economic factors and principally the fact that the interests of the private industrialist in these and other questions contradict the interests of society are the main cause of undesirable interference in the natural processes of the environment.

Modern science and technology are developing means of production based on the application of closed-cycle technological processes which preclude the release of wastes into the environment or reduce these wastes to insignificant proportions, and finding ways of processing solid waste for use as construction materials. In the field of agriculture they are producing highly-selective biological means for counteracting pests and developing fertilisers which have no harmful side-effects. However, the application of many of these methods may be less advantageous from the point of view of the private owner of enterprises or agricultural land, and reorganisation of industry for transition to any one of them may involve tremendous expenditure.

Progress and the Biosphere

Unable to understand the real interrelation between modern scientific and technological development and the environment, some bourgeois researchers come to the conclusion that the conditions of the biosphere are already a factor limiting human society's opportunities for progress.

In our view there is nothing fatal about the problem of society's interaction with the natural environment; it can and will be solved not by stagnation or by turning back the clock of historical

development, but in the course of mankind's further movement ahead.

Here it is important to take account of the unreality of the demand for "non-intervention" by man in nature, the demand that the unchangeability of the natural environment be preserved. Environmental pollution which endangers the health of the population can and must be prevented, but certain changes in the composition of the natural environment are inevitable, albeit by virtue of the fact that the matter of any articles and materials is dispersed during the period in which they are in service (we shall return to this in greater detail later). It is also inevitable that there will be a certain change in the planet's thermal balance as a result of the additional heat given off when energy is used.[1] Certain purposeful changes in the environment — irrigation of arid areas, development of river systems for power and transport purposes, etc. — are essential for the very existence and development of mankind. The scale of these transformations will grow.

This gives rise to an urgent demand for methods of calculating both the short-term and long-term consequences of any impact on the natural environment so that individual elements of these actions tie in harmoniously with each other and lead in total to the creation of more favourable conditions for man. Thus society's interaction with the environment should be based on the systematic, purposeful and strictly planned development of nature, rather than the preservation of a static "natural equilibrium".

We shall return later to the relation between the growth of human society's requirements and the possibilities of satisfying them, and to the question of transforming the natural environment. Now let us turn to what the above authors see as the fundamental reasons for the coming crisis (in their view) in the interaction with nature and what means they suggest for averting this crisis.

According to Forrester and D. L. Meadows with his coauthors mankind has a certain irrational property — a "desire for growth", for increase, for a greater production of all and everything. It should be noted that an attempt to infer the properties and aims of mankind directly from the biological nature of man precludes the possibility of a well-grounded approach to analysing the prospects of social development. In this

[1] More precisely, from the use of energy obtained from fuel or atomic reactions.

way analysis is deprived of actual social content and assumes a formal nature. It is not surprising that in the final analysis the social conformism which is implied in the forecast (although its authors criticise capitalism on many points and incur the wrath of orthodox bourgeois theoreticians because of it), cannot but introduce conservative features into it. Whether this is realised or not, the actual type of man-nature relations which have developed in conditions of capitalism, is made absolute and extrapolated to the whole of mankind and the earth as a whole. In the real world, however, different parts of mankind develop in different ways and have differing trends in interrelations with the environment. In studying the problems of the biosphere it is absolutely essential to take account of the fundamental differences in attitude to the natural environment between capitalist and socialist countries, and those progressive changes which have occurred in the countries of the Third World.

Marx himself predicted that optimal interaction with nature would be achieved in conditions of socialist society. He wrote that socialised man, the associated producers, rationally regulated their interchange with Nature, "bringing it under their common control, instead of being ruled by it as by the blind forces of Nature; and achieving this with the least expenditure of energy and under conditions most favourable to, and worthy of, their human nature."[1]

This circumstance is considered by B. Commoner. In his book he frequently returns to the idea that the main stimulus for the development of a society based on the system of private enterprise — the desire to obtain the greatest profit — creates the very contradiction between the interests of the private individual (the owner of enterprises or resources) and the interests of society.

By examining successively the various aspects of the links between the "crisis of the environment" and economic and social factors Commoner comes to the conclusion that mankind will not be able to avoid an environmental crisis without a radical restructuring of the existing social and economic system in the capitalist countries. He recognises that both in the theoretical bases of its activity and in its practical embodiment (on the example of the Soviet Union) socialist society has a considerable advantage over capitalist society as far as optimisation of its interaction with the environment is concerned. Lamenting (and not without certain

[1] K. Marx, *Capital*, Vol. III, Moscow, 1974, p. 820.

grounds) that "fulfilment of the plan" often prompts the heads of Soviet enterprises to treat the natural environment little better than their counterparts in the USA, Commoner rightly notes that the public and the Government of the USSR have in recent years not only fully realised the danger of an ecological crisis, but taken real and increasingly important measures to avert it.

Naturally, we are far from being satisfied with the present level of optimisation of the biosphere and should like to raise it primarily by cutting down the expenditures on arms and scientific advancement in the military field which socialist society is obliged to maintain.

Despite these opposing aspects socialist society as a whole is optimising its interaction with the natural environment and opening up prospects for the whole of mankind.

Of fundamental importance in this respect is the inclusion of questions of environmental protection, the rational use of natural resources and the prevention of any effects being produced on the environment for military or other hostile purposes in the Peace Program advanced by the 24th Congress of the CPSU and developed by the 25th Party Congress.

At the 24th session of the UN General Assembly the Soviet Union raised the question of the need to remove the danger of changes being induced in the environment and the climate for military or other purposes not compatible with the interests of international security and people's health and well-being, and put forward a draft international agreement to this end. Thus the question of man's influence on elemental phenomena became for the first time the topic of international negotiations. The conclusion of a comprehensive international agreement on the prevention of the development and use of the means for influencing the environment for military and other purposes hostile to man would constitute a serious contribution to the strengthening of peace and the first instance of the timely banning of weapons which do not yet exist, but which may appear in the not-too-distant future.

The questions of environmental protection occupied an important place in the Final Act of the Conference on Security and Cooperation in Europe (signed on August 1, 1975 in Helsinki) which was convened on the initiative of the Soviet Union and other socialist countries.

In the Soviet Union, as in other socialist countries, prevention of

environmental pollution and rational (in the long term) use of natural resources follows naturally from the essence of the socialist system. As the economy develops, increasing attention is being paid to this problem and more and more funds allocated for solving it. Complexes of measures on the protection of nature are becoming part and parcel of general state plans of economic and social development.

In the USSR major work is proceeding on land improvement and the prevention of wind and water erosion of the soil; better use is being made of water resources, forests and minerals. Valuable and rare species of animals are protected by the state; the fishing industry is being better zun. Serious attention is being given to measures on the air and water pollution control, improvement in the heating and gasification of cities and other populated areas, and in abating noise pollution. There has been a considerable increase in the size of capital investments for the implementation of nature protection measures, and in the construction of sewage treatment, gas purification and dust-catching installations. In recent years the Central Committee of the CPSU and the USSR Council of Ministers have adopted a number of decrees on measures to prevent pollution of the Caspian, Black and Azov seas, the Volga and Ural river basins and Lake Baikal. The Supreme Soviet of the USSR has approved the principles of public legislation relating to land, water, mineral wealth, and public health. The Union Republics have adopted corresponding laws and codes. The CPSU Central Committee's report to the 25th Congress noted that regulations for nature protection on a countrywide scale have been worked out. There was wide discussion on the improvement of environmental protection and rational use of natural resources at the 1972 and 1975 sessions of the USSR Supreme Soviet. The Supreme Soviet acknowledged that constant attention to the nature protection and better use of natural resources to create the best possible conditions for the life, health, work and recreation of the working population was one of the most important state tasks.

All this provides convincing evidence of socialist society's desire to harmonise its interrelation with nature, and the practical steps taken for this purpose.

The Soviet Union considers it absolutely essential to maintain broad international cooperation in organising the correct interaction between society and nature. The agreement between the

USA and the USSR on environmental protection signed in May 1972 and the Soviet Union's extensive activities in this field in cooperation with the CMEA member-countries and other countries of the world satisfy the urgent need for mankind as a whole to set a definite goal — the optimisation of interaction with the natural environment of the whole planet — and outline a long-term agreed program to achieve it.

Stagnation or Progress?

Examining the various combinations of predicted parameters up to the middle of the next century J. Forrester and the authors of *The Limits to Growth* point to the fact that if they continue to grow at the present rate the inhabitants of the earth may begin to die out on quite an intensive scale in 50 to 70 years' time. It is hinted in this respect that if the Third World countries do not become industrialised, they will be less affected by this "universal plague" of the future.

Commoner does not give such a specific description of the result which the development of the current crisis of the natural environment may produce, but still considers it a general global crisis, a collapse.

The authors of *World Dynamics* and *The Limits to Growth* believe that the only way to avoid this sad fate is to limit the growth of all parameters (population, consumption, pollution, production) and establish a "state of world equilibrium". To substantiate this backward movement in history from the philosophical standpoint the authors make use of the theory of rotation quoting the famous remark of Heraclites that in a circle the beginning and the end coincide.

Commoner also advances the concept of the "closing circle". Rightly turning our attention to the fact that one-way anthropogenic processes on the planet could only be permitted while the amounts of matter and energy involved were insignificant as compared to natural phenomena, he presses for the transformation of man's entire production activity in such a way that the cycles of matter and energy which it gives rise to are closed without fail. From his point of view this means the need for complete and harmless assimilation by the natural environment of every end product of human activity.

If we take the present cycle of matter and the balance of energy on the planet as a firm basis here, the introduction of substances

into economic activity, which cannot be assimilated by the natural environment, such as synthetic fibres or detergents, and fossil or atomic fuel, is not permissible, for in the long run this will lead to an imbalance of the geochemical, energetic or other elements of the natural balance of the environment.

In this context Commoner believes that it is essential to bring about a corresponding reorganisation of industrial and agricultural production, first in the USA, and then in the rest of the world. The transition to "ecologically based" industrial and agricultural technology should be accompanied by the introduction of control over the growth of population, production and the volumes and rates of cycles. This is also a call for a stable balanced state.

The authors thus display a particular conception of ecological pessimism which, irrespective of the subjective intentions of the authors, objectively turns into an apology of stagnation, a rejection of the humane idea of social progress. From our point of view such an approach is surely an extreme in relation to the rationally understood program of the optimisation of the biosphere.

Against the assertions of the neo-Malthusians the potential for satisfying the basic needs of man which arises from a comparison of the known and potential resources of our planet, the means of production and the size of population has always grown and continues to grow faster than population. This is a characteristic of human development. In a polemic with the Malthusians of his time Lenin noted that the so-called "law of diminishing returns" could only have a conditional significance if technology remained unchanged, and that this law was completely invalid in the case of technological progress.[1] Society is constantly changing its means of interaction with the environment—the mode of production in the broad sense of this word.

"Malthusian impasses" could have arisen at any stage of human development, if technology had not progressed, if the modes of production had not changed. Catastrophes of this kind with the volume of resources remaining unchanged take place from time to time in the biosphere due to accelerated growth of the number of organisms in their habitation area. Here the balance can only be restored if the numbers decrease as a result of death or mass migration beyond the area. Plants and animals cannot change or raise the effectiveness of their interaction with the environment

[1] V. I. Lenin, *Collected Works*, Vol. 5, pp. 107-120.

other than in the extremely slow process of biological evolution. This is not true, however, of mankind.

In his note "From the Field of History" Engels wrote: "The normal existence of animals is given by the contemporary conditions in which they live and to which they adapt themselves—those of man, as soon as he differentiates himself from the animal in the narrower sense, have as yet never been present, and are only to be elaborated by the ensuing historical development. Man is the sole animal capable of working his way out of the merely animal state—his normal state is one appropriate to his consciousness, *one that has to be created by himself*."[1]

The biosphere is a product of the life activity of organic forms and at the same time an object of man's activity. By virtue of this fact the biosphere should be regarded in comparison with the trends in the development of human activity. Statements on the inadmissibility of unsystematic, chaotic disturbances of the given natural state of the biosphere are completely fair. However this state cannot be considered as the only possible one. In our view it is possible (and one day it will be inevitable) to have a purposeful, systematic change of the biosphere—increasing its effectiveness in the broad sense of this word—in accordance with the growing needs of human society. Mankind is capable of developing progressively, provided that it takes account in its activity of the tasks of optimising the biosphere. And optimisation of the biosphere is essentially a form of optimisation of human activity.

The Biosphere and Human Activity

Drastic increase in the scale of human activity in the conditions of the modern scientific and technological revolution changes considerably the interrelation between society and the natural environment. Instead of the weak man who was quite often repressed by nature during the early stages of history we see the technologically powerful man of the modern era who in certain cases is capable of repressing the environment.

Over a considerable period of human history natural resources seemed infinite against the relatively insignificant use to which they were put and the small population of the earth. The discovery of resources and efficient extraction from the natural environment

[1] F. Engels, *Dialectics of Nature*, Moscow, 1974, p. 195.

were thought of as man's main task as regards his interaction with nature.

The depletion of certain natural resources, primarily minerals, at the turn of the century reminded us that they were finite in the context of the rapidly and, it seemed, infinitely growing needs of mankind. Numerous researchers set about calculating the total potential reserves of the planet's non-renewable resources and laid down likely periods in which they would deplete. The depletion of certain important natural resources such as coal or oil was regarded as a serious threat to the well-being of man. It was thought that mankind's crisis in its interaction with nature would be caused by a shortage of raw materials or fuel.

But in fact two processes develop: on the one hand, more and more reserves of minerals are unearthed, which produces a rapid increase in their known volume on the planet despite growing (at a slower rate) consumption; on the other hand, there is an equally rapid increase in man's ability to convert substances from one form to another, the ability to produce "everything from everything", which reduces man's dependence on specific forms of natural resources; finally, fundamentally new ways present themselves of satisfying man's needs for food, energy, materials, etc.

It is difficult to give a quantitative evaluation of this capability, but numerous examples point to the fact it increases at a faster rate than the depletion of any particular natural resource. Atomic fuel has appeared, although the known reserves of mineral fuel, far from running low, continue to increase. Despite the vast reserves of agricultural production the first successes have been recorded in the creation of synthetic food (as yet as fodder for animals)

This means that all the matter of the earth and subsequently all the matter of space accessible for use by man will gradually become the single and universal measure of natural resources as people learn to obtain "everything from everything". At the moment the irreversible consumption of matter on the earth is extremely small: it takes place in the production of atomic and thermonuclear energy and the launching of vehicles into space. It comprises but an insignificant proportion of the constant exchange of matter between the earth and space. Every day the earth receives several thousand tons of matter from the meteorites and various other particles which reach it from space and at the same time loses several hundred tons of matter from the dispersion of gases from the upper layers of the atmosphere.

This once again makes the volume of natural resources practically "infinite" in comparison with their use by man, especially as it is quite probable that we will be able to use not only the matter of the earth but that of planetary bodies situated a relatively short distance away from it.

Optimisation of the biosphere requires that the development of production is on no account accompanied by an increase in waste. This is not easy to achieve, especially as the problem of removing waste comes up against the laws of conservation—in a closed system any form of removal of wastes will somehow or other include them in the natural process. Here the very concept of a closed system is not constant. What is today outside a certain closed system, turns out tomorrow to be an internal element of a more extensive super-system. By releasing wastes higher into the atmosphere where the wind speeds are higher we have successfully removed wastes from the cities. But when the whole atmosphere is saturated with this form of waste the height of the chimney loses its significance: in a more extensive closed system the laws of conservation of wastes will have their effect just the same. By virtue of this we need other, more radical means of dealing with wastes such as chemical treatment and purification plants. Commoner has considered many aspects of this problem.

Those elements which today go beyond the bounds of the finite field of application of our experience may tomorrow form part of a closed system of a higher order which will serve as a base for the science and technology of tomorrow. Here the very concept of the biosphere as the sphere of the living is generalised. It is not merely the outer envelopes of the earth, but the regions of space lying close to the earth and the inner reaches of the planet from which the resources necessary for the further development of man will be drawn. The spatial expansion of the sphere of human activity determines the contradictory nature of the interrelations between the finite and the infinite in the area under consideration.

The ecologically unacceptable pollutants and wastes which are now appearing in the transformation of substances in production, can and undoubtedly will be eliminated. But, as has already been pointed out, we will not be able to eliminate less marked but growing changes in the composition of the environment due to the inevitable dispersion of a part of the substances while the objects produced from them are in service. As a result of corrosion, for example, a small percentage of the matter of products made from

iron is dispersed. The natural environment is constantly being "enriched" (or "poisoned") not only by the wastes of production, but by various elements which form a part of the useful products of our activity. Substances which are introduced by various means into the natural environment as a result of geophysical processes first of all disperse, but subsequently concentrate due to biological processes and eventually accumulate in the organism.

In our view it is in principle feasible to overcome possible harmful effects of this inevitable dispersion by introducing appropriate compensating processes, e. g., removal from the environment by means of controlled concentration using biological means, or neutralisation of the action of certain substances by others. This problem may become rather serious. In order to solve it we should work out sufficiently accurate calculation methods and develop methods of controlling certain processes in the biosphere.

Interesting and important problems arise from the change of the planet's energy balance.

All man's activity is accompanied by heat pollution. At the present moment anthropogenic heat comprises from 0.01 to 0.02 per cent of the thermal energy coming from the sun. This is still a very small amount. But if the present growth of energy production continues one can suppose that in 50 to 70 years' time it will increase to 1 or 2 per cent, which could have serious consequences.

Here we should recall that processes in the natural environment sometimes reach an unstable state. Methods of transforming the weather, preventing hail and dispersing clouds are based on using the instability of meteorological processes.

Similar instability may, however, occur in the processes of climate formation. If this is so, phenomena such as a rise in temperature of 1 or 2 degrees may act as trigger mechanisms capable of transferring large-scale processes from one state to another.

This has its favourable and unfavourable aspects: favourable because it enables us to bring about major changes, even changes in climate, using relatively minor resources (arbitrary "selection" of climate is, of course, impossible due to the close link between all natural factors); and unfavourable because disturbances of balance may take place whether we desire them or not in such a way that we do not notice them.

It is impossible to avoid the release of additional heat[1] but it is possible in principle to avoid its undesirable consequences, e. g. by compensating for the effect on the thermal balance by regulating the amount of cloud.

In addition to questions of matter and energy, information systems linked with cybernetics will come to play an increasingly important role in the optimisation of the biosphere. These view man and the natural environment as internal elements (or rather subsystems) of an extremely broad system. This system has the ability to regulate itself, while its elements (man and nature) to a considerable extent lose the ability for self-regulation independently of each other. In this respect nature acts not simply as something external to man's activity, but as its internal (within the bounds of sociobiogeocoenosis) condition.

In the future man's regulative activity will become an increasingly significant factor restructuring (more and more radically as time goes on) the natural environment in accordance with the needs of the progressive development of society. Scientific information and various technical means will be needed for this in increasing quantities.

It is interesting to consider the growing possibilities of transforming the environment to suit man's purposes. Over a long period of human history natural phenomena conditioned the relatively narrow bounds of conditions suitable for man's existence and activity. It was impossible to overcome them and the infavourable influence which they exerted in many cases represented the main danger for man.

Today we see the conclusion of the stage of adjustment to the natural environment and protection from the unfavourable influence of elemental phenomena which enabled man's activity to be guaranteed in any conditions encountered on our planet.

The main danger for man at present is his own influence on nature over which he himself has as yet little control. But this in no way means that he will slide irreversibly towards ecological catastrophe: social progress determines the possibility of overcoming this danger.

In grasping the new opportunities for exerting a favourable influence on natural processes it is essential and feasible to prevent

[1] For this one would have to make use of just direct solar energy, and energy from water and wind, which would not be sufficient.

at the same time not only short-term but long-term negative consequences of this influence. Man remains the master of the situation and, if he observes certain conditions, is capable of achieving harmony in his relation with nature.

There are many different stages involved in solving the problem of harmonising interrelations between man's technological activity and the natural environment. Such a solution is no once-and-for-all affair, but a constantly developing contradictory process which, if it is to become a reality, requires in the era of scientific and technological revolution and man's complete mastery of nature not only systematic efforts but essential reorganisation of the very structure of human activity.

In the first stage of such a reorganisation individual measures aimed at environmental protection (e. g. introduction of cycles into chemical production, construction of various kinds of purification plants, taller factory chimneys, replacement of the internal combustion engine by the electric motor for urban transport, etc.) should merge into an integral system of specially planned activity compensating for the effects of production and consumption which harm the biosphere. The compensating part will be singled out from the whole production activity. It may assume considerable proportions over the next two or three decades. Subsequently, however, we believe that as man develops new wasteless production based on closed-cycle technology, and as there is increase in our knowledge of the mechanism of natural and artificially stimulated processes in the biosphere and a corresponding increase in the opportunities for controlling the processes of the biosphere, individual, specific compensating activity should become superfluous. Mankind's production activity as a whole should embrace the totality of processes occurring in the biosphere in such a way that all the elements of this activity, both those produced directly by man and those proceeding under his influence and control in nature, represent a harmonious whole.

Any well-organised agricultural enterprise is an example of such a system at the present time.

In this context logical constructions which make absolute man's disruptive action on nature are completely untenable. According to them man can only develop his organisation by intensifying chaos and disorganisation in the natural environment. We believe that to optimise the interrelation between man and nature it is necessary to approach the whole natural environment not as something

external or even hostile to man, but as one of the most important elements of the sociobiogeosystem.

One of the essential elements of man's responsibility for his future is the responsibility for the fate of nature, since a gap between the subsystems mentioned above would mean the degradation of living things and eventually the extinction of man. (As we know neither radiation, chemical pollution nor other negative consequences of man's activity have a disastrous effect on certain lower forms of life.) The negative aspects of the technological and urbanised civilisation which have appeared in recent years, far from casting doubt on the Marxist concept of "humanisation" of nature in practical activity and theoretical knowledge, demand that it be further strengthened and developed.

As we have already pointed out, not just the irretrievable consumption but the cultivation of renewable natural resources by man has increased throughout the entire history of mankind. This means essentially increase in the degree of organisation of the element of nature which is included in economic activity and regarded, of course, in conjunction with the part of economic activity which relates to it. By switching to cultivation of renewable resources and to the transformation of the natural environment on a planetary scale (i. e., organising a "biotechnosphere") we increase the order in the part of the Universe accessible to us, and in no way contribute to a growth in chaos. Increase in the enthropy of the flow of all forms of energy used is of no great significance in this particular case.

It is quite clear that in the process of optimisation of our interaction with nature the advantages of a social system based on collective property are fundamental.

For all its complexity the problems of this optimisation are quite resoluble. The tremendous amount of money needed for this will be provided in increasing volumes, particularly as the arms race is curtailed as demanded by all people of good will.

Modern science will provide the vast amount of information of various kinds needed to resolve these problems.

To extend our knowledge of the processes in nature in their interaction with technological development we must touch on such a variety of phenomena that they cannot be fully included in any one of the existing scientific disciplines in isolation. This gives rise to an urgent demand for a complex analysis of technogenic impact on the environment. At the same time we do not think that it is a

matter of creating another special science to describe the interrelation between society and nature or the determination of another "sphere". We believe that what is required is the development of some sort of synthetic interdisciplinary view on the role of environmental processes in man's future progress.

By delving deeper into the objective truth in the processes of the biosphere man will be able to combine intelligently the transformation of nature with the necessary harmonisation of his interrelation with it.

THE ENVIRONMENT AND SOCIAL PRODUCTION

Pavel OLDAK, Dr. Sc. (Econ.)

In the late 1960s, at the acme of brilliant achievements in science and technology, when man had harnessed atomic energy, learned to create new materials, deciphered the genetic code and sent men into space and rockets to the planets of the solar system, the world's attention turned to the problem of the environment. And what is more, many people were surprised to learn that they were faced with a problem of calamitous proportions.

Disquieting information began to pour in from all directions that the most important natural resources—the oxygen of the air, the purity of fresh water and the water of the World Ocean, the earth's temperature regime and the diverse animal kingdom—were threatened, that modern production had come up to the boundary beyond which the basic conditions of man's life on earth began to break down, and in some places already crossed this boundary.

In his time Frederick Engels wrote: "Let us not, however, flatter ourselves overmuch on account of our human victories over nature. For each such victory nature takes its revenge on us. Each victory, it is true, in the first place brings about the results we expected, but in the second and third places it has quite different, unforeseen effects which only too often cancel the first."[1]

This observation has not lost its significance. On the contrary, the development of industry, the growth of cities and the creation of increasingly powerful means of transportation have brought about a considerable increase in the load on the environment.

It will only be possible to assess the full significance of these processes at some time in the future. But it is already evident today that man has begun to interfere in the profound processes of

[1] F. Engels, *Dialectics of Nature*, Moscow, 1974, p. 180.

development of life on earth, thereby worsening the conditions of his very own existence.

Researchers have come up against a number of serious methodological problems in attempting to assess ecological prospects for the future. First and foremost it became clear that they had to examine much longer periods than those for which the processes of man's impact on nature were investigated until quite recently. This involved switching from long-term forecasts (10 or 20 years) to super-long-term forecasts (30, 50, 100 or 150 years), for it is only by examining long-time intervals that we can produce a complete description of the processes of interdependence between society's development and the environment.

The future is like a sharp sword. Recognise opportunely the problems of the future and you will grasp the hilt of the sword in good time. Miss the opportune moment and you are faced with the need to grasp the honed blade of the sword with your bare hands, that is to correct the unfavourable development of events hastily and at the cost of great losses, and not to use one's opportunities to the full.

But to understand the future it is not sufficient to investigate just the "technical links"—the interdependence between natural and economic parameters inside a particular socioeconomic system. It is essential to analyse this system itself.

The Link Between Social Production and the Environment

With the present-day scale of transformative activity nature can no longer support independently the normal conditions for the development of life on earth, and the burden of solving this problem is shifting increasingly onto human society. Having reached up to the heavens man must henceforth bear them on his shoulders like the mythical Atlantes.

Radical change in the correlation of forces between man and nature is one of the greatest landmarks in the history of human society. The coming of a new era requires a new stage of development not only in scientific research, but also in social thought. It is essential to recognise the strict dependence of the development of society on the maintenance of the equilibrium of the entire ecological system of life on earth. Modern man should match the great power which he has acquired with great intelligence. Man is a

creator, but not an irresponsible creator. He is predestined to realise the most vivid dreams, but only if he does not destroy the medium of his own habitation "on his way to the stars".

Today we find a rigid two-way dependence between the system of social production and the environment. It is expressed in the fact that stable development of production and the all-round development of the personality (the span of life, physical health, complete satisfaction of man's vital needs and fulfilment of his creative potential) can only be realised if the purity of the environment is preserved; the latter is, in turn, only possible if there is a transition to forms of transformative activity which take account of the requirements of neutralising wastes from production and consumption.

Analysis of this dependence shows that natural (ecological) processes and man's economic activity cease to develop as detached systems; they close up and grow into a single "production-environment" metasystem, or bioeconomic system. Accordingly the problem of controlling social production begins to develop into the tremendously complex scientific problem of controlling a bioeconomic system.

We still know very little about the nature of the bioeconomic system and the requirements which should be borne in mind to ensure stable and harmonious development of its subsystems (social production and the environment). The material accumulated has generally speaking received insufficient theoretical interpretation and generalisation. Nevertheless it may be said that a new branch of research—the theory of control of bioeconomic systems—is developing at the junction between ecology and economy. This new science could be called *bioeconomics*. Bioeconomics is based on the results of research in both natural and social sciences. At the same time it has its own objective—the study of the interrelation between the rate of economic growth, the level of technology and the quality of the environment.

Analysing the bioeconomic system constitutes one of the major problems of the modern era. The vital need to formulate the laws governing the maintenance and development of this system has given a powerful stimulus to the development of a number of spheres of knowledge. It was this very need which pushed ecology—a science which until recently was the preserve of a small circle of experts—into the front rank of the disciplines which

determine the modern stage of cognition of the world. The range of problems touched on by philosophical research is broadening. Increasing attention is now being given to developing a new attitude to nature as one of the most important aspects of modern world outlook. The task of conserving the environment has determined a new field of technological research—the development and application of closed technological cycles and the complex use of raw materials, which in turn presupposes fuller utilisation and neutralisation of production and consumption wastes.

But the environmental problem is having perhaps its most profound impact on the development of economic science. The transition from a conception of social production as an isolated system to analysis of the interrelation between production and the environment serves as a definite borderline for the development of economic ideas. We are gaining a broader idea of the boundaries of social production, the aims of economic development, the essence of the notions of national wealth and national income, the demands made on long-term planning, the problems which the system of economic regulation should resolve, and the criteria for assessing the effectiveness of the decisions taken.

Until quite recently social production was thought of as an open system which takes the initial raw materials and releases the wastes into a medium external to itself. An open system is based on the principle of one-time use of the natural starting material and in this sense constitutes a peculiar form of "open end" economy. In fact production uses only a part of extracted primary materials. The rest is converted into waste.

Progress will always take the form of destruction of the old and affirmation of the new. But the larger the scale of social production, the fewer the opportunities for having an "open end" economy and the more urgent the demand for a switch to a different, higher form of economic interaction with nature.

This may be represented figuratively in the following way. In the past we took some "building blocks" of natural resources and created economic wealth from them, converting half or more of these "blocks" into waste. In due course the outmoded economic wealth also became waste; production, however, continued to seek new "blocks" of natural resources.

This sort of management of our planet will be impossible in the future. We need a consistent transition to what might be called a closed system of production.

The essence of this system is that it is based on the repeated use of these very same "blocks". The latter presupposes two extremely important conditions. Firstly, primary natural resources should not be extracted each time for separate types of end product, but at one time for all possible types of economic wealth. Secondly, the products created should be of such a form that after use for their own direct purpose they may be converted relatively easily to the initial elements of a new production process.

A closed system may be considered as consisting of two subsystems, one which *uses* the elements of the environment (that is, converts nature's products into economic wealth) and one which *restores* the used elements of the environment (by this we mean, on the one hand, the conversion of the wastes of economic activity into raw materials for new production cycles, and on the other, the restoration of the disturbed ecological equilibrium). The switch to the closed system—a continuous cycle of matter in the production process, where the processing of waste will constitute the last link of one cycle and the initial link of the next—is one of the most important demands of the modern stage of economic development.

The Social Aspect of Analysing Bioeconomic Systems

Analysis of the internal link between the development of social production and the state of the environment brings into even bolder relief the problem of affirming the advanced social forms.

As we know, the process of environmental pollution is farthest advanced in the industrialised capitalist countries—a state of affairs which cannot be regarded as accidental. The capitalist mode of production, which is based on private ownership and aimed at achieving maximum profit, inevitably leads to a situation where the development of production is bought at the cost of environmental damage. In the past we criticised capitalism as a system which exploits the working people, and engenders unemployment, crises and imperialist wars, whereas today we also emphasise a new important aspect—the destruction of national and planetary systems of life support. The capitalist system of production is at variance with the interests of preserving the environment, a fact which is becoming clear to increasingly broader sections of society.

The production of fundamental wealth in bourgeois society is marked by the creation of more and more consumer goods for the continuous accumulation and renewal of property and the stimulation of artificial demands. Today the false orientation of this kind of production is plain for all to see. It has engulfed the consumer in a world of material things and turned property and the renewal of property into a prestige factor, a means of demonstrating and affirming one's position in society. The consumer society with its property cult is hostile to nature. Modern industry in its present form gnaws into nature in an increasingly rapacious way, undermining the basis of man's life on earth.

The purity of the environment is a natural blessing for mankind. And the countries where the accelerated growth of production proceeds at the expense of this purity are nothing like as prosperous as it might appear. Tokyo smog is so thick, for instance, that its inhabitants ask themselves more and more often whether the advantages of owning one's own car outweigh the disadvantages of breathing polluted air.

Thus, in the initial stages of analysing bioeconomic systems one realises the historical limits of a production system which proceeds without national economic programs, is oriented only towards extraction of profit and cultivates the social standards of the consumer society. It is not difficult to see that the limiting factors of the capitalist system—the principles of private capitalist production and the bourgeois conception of the value of fundamental wealth—appear from a new point of view.

At the same time it would be incorrect to always link environmental pollution rigidly with capitalism. There is more to the problem than that. It has its roots in both social and technological factors. By the latter we mean the lag between the technology of modern production and those requirements which are dependent on the rapidly increasing load on the environment. This lag is due to a number of reasons, among them the inertia of production (the long period for which developed technological systems are in use) and the inadequacy of scientific research. One can single out, in particular, the narrow spectrum of ecological research, the small amount of work done on the technology of closed-cycle production and the failure to develop the criteria for assessing the effectiveness of production development with due regard for the restoration of the environment.

The limited nature of resources is also a significant factor. If one takes account of expenditure on research, the development of new technology, the re-equipping of production and the rehabilitation (albeit partial) of destroyed ecological systems, conservation of the environment is becoming almost the largest and most expensive program. It will only be feasible to set aside sufficient resources for it, if there is a significant advance in the field of international detente and the curtailment of military programs.

In the context of technology the problem of environmental protection is of a general nature and concerns the two socioeconomic formations of the modern era.

The Notion of the Metapotential of an Economic System

Man has striven for millennia to conquer nature. But when he had achieved his greatest victories, there appeared the urgent need to "protect nature".

Essentially man needs to find the correct fusion of the interests of the present and the future. We must not ignore the interests of the present, or sacrifice the interests of the future. We must not, for the sake of pure love for nature, prevent its economic utilisation. But neither must we squander the capital of nature, forcing society in the near future to spend colossal amounts of money and effort on restoring the general system of life support. "For us and our grandchildren"—this is the demand which is being made more and more urgently on social production.

Rational combination of the interests of the present and the future presupposes that in future labour expenditures should be accounted for in economic decisions being taken.

This is a fundamentally new task. It is well known that since the birth of scientific ideas on the nature of economic processes almost three centuries ago economic analysis has revealed and compared the expenditure of materialised and live, i.e., past and present, labour.

Today we see that economic decisions should be considered from the standpoint not only of expenditure on the production of goods and services, but also of the labour that will be needed to make good the damage caused to the general life support system by the production and consumption of the corresponding goods.

This is certain to produce a considerable change in the

composition of a number of the most important economic categories, and specifically a certain broadening of the concept of national wealth.

Until quite recently national wealth was interpreted as a category describing the sum total of production for a given year. Some economists associate the concept of national wealth with the size of accumulated material values—the material results of production; others with the size of the flow of reproduceable wealth—goods and services. It is obvious that in both cases attention is concentrated on the present. At the same time today, as we have pointed out, we find an increasingly close link between the present and the future. Consequently, analysis of the results of production is coming to embrace the growth potential of the economic system when normal conditions for the development of life are maintained. In other words, attention is moving from the level at which the economic system satisfies the needs of the present to the level which determines the opportunities for development and satisfaction of the needs of the future. The concept of wealth as a product should, it seems, be combined with the concept of wealth as a potential for economic growth.

By virtue of the fact that the opportunities for development are dependent upon a number of quantitatively heterogeneous elements, let us employ the concept of metapotential (MP). By MP we mean a generalised description of the power (potential) of detached national systems, and consequently the extent of their impact on the future situation. We can distinguish four aspects which describe the MP of a national system: 1) economic potential, 2) scientific and technological potential, 3) human potential, 4) ecological potential.

Economic potential reflects the level of output of the end national product. Scientific and technological potential— education, science, management—describes the accumulated reserves of growth. Human potential—the size of the population, its physical and mental health, and the level of creative activity—characterises the social conditions for using the available development opportunities. Ecological potential—the degree to which the purity of the environment is maintained—reflects the boundaries of possible expansion of production without the apportionment of great resources for the rehabilitation of the damaged environment.

The concept of MP enables one to see clearly that an index such as the gross national product (GNP) does not describe in full the

effectiveness of the development of a particular national economic system over a given period. GNP describes the growth of only part of the MP. If the GNP has grown in one particular country, this can only mean a growth in the MP of the system if the other elements of the MP have not suffered a decrease. If, however, a growth in the GNP goes hand in hand with pollution of the environment and deterioration of the population's health, which is the case in the industrialised capitalist countries, then it is not known whether the MP of the system has increased or decreased.

Until very recently GNP was regarded as the most generalising index of economic development. A high rate of growth of GNP was considered as reliable evidence of progress, almost a synonym of the economic achievements of society. The experience of the 1960s, however, prompts one to think seriously about this. In Japan, the USA and a number of capitalist countries of Western Europe demands are being made that the GNP no longer be considered the supreme aim of economic development, that this growth be decreased and a portion of the resources be redirected into conservation of the environment.

Several bourgeois economists in the West are now advancing the concept of zero growth, which is based on the idea of holding back the rate of economic development. Despite the fact that this concept proceeds from an analysis of real contradictions, its overall conclusion cannot be acknowledged as being correct. It is unacceptable first of all in the social respect. A zero growth rate would really mean the maintenance of the existing division of countries into "rich" and "poor", and consequently the consolidation of the developed capitalist countries' advantageous position. The peoples of the developing countries can obviously not agree to such a state of affairs. The demand for a zero growth rate is also unrealistic in the purely theoretical respect: it is impossible to halt economic development, for it is born not only of the need to satisfy man's requirements for material wealth, but also of his striving to apprehend the world and manifest creative abilities.

A distinction should in our view be made between the growth and development of an economic system. Growth describes the increase in the system's productive potential, the raising of its "weight category", if one may express it in this way. Development, on the other hand, reflects the ability to realise specific programs. It depends not only on the "weight category", but also on

qualitative parameters such as accumulated knowledge, the state of the human factor and the environment.

One of the most important factors in the development of an economic system is the level of technology; the extent to which the production systems in use are closed serves as an index of this. It is obvious that under modern conditions stable growth rates are closely linked with progress in the field of production technology. The higher the level of technology, the greater the growth that can be guaranteed without destruction of the environment. Contrast between the demands for production growth and the preservation of the quality of the environment is only present in medium-term programs. Here in the interests of an economic manoeuvre it is possible to ensure an increase in the growth rate by limiting expenditure on the preservation of environmental quality. But both social criteria and the purely economic demands made on the quality of the biosphere's resources place extremely narrow limits on such a manoeuvre. And if we move to long-term programs, then it turns out that the achievement of stable growth rates is inseparably linked with the improvement of technology to ensure that certain limiting parameters of environmental quality are maintained. And it is the MP which describes the ability of a system to realise long-term development programs.

With the help of specialised research it will be possible to show what the correlation between the main elements of MP should be for the economic system to realise the most extensive development program for the given initial conditions (manpower resources, natural resources and accumulated production funds). This will characterise the normative structure of the MP. By comparing the normative structure with the actual one it will be possible to determine the priorities for the growth of different elements of MP.

Determination of the structure of MP and selection of preferable growth rates raises the question of measuring the MP elements. The complexity of the problem lies in the fact that to compare the elements of MP which belong to the qualitatively heterogeneous links of the bioeconomic system we need a new, broader unit of measurement than the one that has been used so far.

As we know, economic science has from its earliest days right up to the present operated with the standard of measurement which was developed within the framework of commodity exchange, namely the category of value. Value has been the universal standard for ascertaining the relative worth of the results of

economic activity, for it has served as a single yardstick for measuring qualitatively different kinds of labour. Value has also been recognised in the socialist economy as a general economic unit of measurement.

But as soon as we go beyond the realm of purely economic activity, value ceases to be a general quantitative measure of worth. Naturally the accumulation of knowledge, the maintenance of public health, and the preservation of the environment's equilibrium can be expressed in units of expenditure on achieving the appropriate aims. Such measurement is of great significance when considering the extent of restructuring the MP an economic system can allow itself inside the chosen interval of time and for a given initial position. But it is possible to have a number of different variants of MP corresponding to a certain given size of expenditure. Which of them is to be regarded as the most preferable? To answer this question we need to have an idea of the normative structure of the MP and the framework of reference which allows the degree of approximation to the normative structure to be determined.

Here we have come right up to the determination of the principles of a new measurement system: the elements of MP should be compared not just in terms of the size of expenditure, but in terms of the correlation of the contribution to the achievement of an integrated result, to the fulfilment of those "ultimate ends" which the economic system undertakes for the period in question. A solution to this task, which merits special attention, may be achieved, we believe, by building a "tree of aims" and assessing the relative importance of each of its elements.

Change in the Assessments of the Effectiveness of Economic Decisions

Up until now economic assessments were restricted to the comparison of direct input and output. Technical solutions were thus considered effective if the product obtained or the service rendered enabled requirements (or, as was more often the case, demands prompted by the very production of new wealth) to be met more satisfactorily. Economic decisions were considered effective if the selling price of the product (service) exceeded by a certain margin the cost of production. It was tacitly supposed that the completion of the production process—the creation of the product or service—was a summary of the final results of the work done.

While man's impact on his environment was limited and nature herself made good the damage caused by production, this sort of calculation was quite sufficient. Now that there has been a sharp increase in production's secondary, tertiary and even more distant effects on nature, to limit ourselves to a comparison of direct input and output is to obtain not simply an incomplete picture of the real state of affairs, but frequently a false picture.

The time has come, it seems, to broaden the systems of economic assessments. This applies first and foremost to the notion of economic efficiency. Today it can no longer be measured by the ratio of the effect obtained (the value of the product or the amount of profit) to the expenditure that produced it (production costs or advances). Expenditure on overcoming the consequences of environmental pollution is now acquiring increasing importance together with expenditure on the creation of the product. These could be defined as *reproduction* costs.

Until now these costs have not been taken into account in evaluating the efficiency of a specific line of production. But if individual enterprises are spared the necessity of bearing reproduction costs, this means that society as a whole sustains them or that it pays in some other ways for refusing to make good the expenditure on maintenance of the normal process of reproduction.

And so we arrive at the conclusion that it is essential to take account of the entire social costs of production, i.e., the amount of directly productive and reproductive expenditure.

The primary tasks will be to assess the complete social costs of production of the entire end product inside the specific economic region. This calculation is of great significance in revealing the relative efficiency of production in various regions of the country and primarily in comparing developed and developing regions. The fact of the matter is that in developed regions the production load per unit of the biosphere's resources is very high; by virtue of this the index of the costs needed to maintain a normal reproduction process will be extremely great. Conversely, in regions of primary development the production load per unit of the biosphere's resources will be small (it is often lower than the level which ensures natural self-renewal of resources). This means that the reproduction cost index will be small or even nil.

Calculation of the total social costs of production and of each given industrial enterprise is of great importance. Comparison

between the effect obtained (the value of the product or the amount of profit) and the amount of the total social costs of production gives an index which describes the integrated efficiency of production.

Socialist economics cannot be oriented simply towards the solution of the tasks arising out of the current needs of society. The solution of future tasks is also extremely important. These include the development of education and science, the restructuring of production and improvement of its technical equipment, the levelling out of social differences and the raising of the standard of living. From this it follows that a stable growth rate must be maintained in the long term.

"Guidelines for the Development of the National Economy of the USSR for 1976-1980", which was approved by the 25th Congress of the CPSU, defines the elaboration and implementation of measures on the protection of the environment and the rational use and reproduction of natural resources as one of the tasks of the tenth five-year plan.

In order to resolve these tasks in sufficiently short periods and with a minimum of expenditure it is essential to rely on a carefully coordinated work program embracing such spheres as science, production and management.

ENERGETICS FOR THE FUTURE

Academician Nikolai SEMENOV

Modern science and technology provide truly enormous prospects for the complete—though of course rational—satisfaction of the basic material needs of all people of the Earth. The attainment of this great goal is limited not by our scientific and technological potential, not by human and material resources, but by social factors, by the persisting institutional imperfections of human society.

Of pivotal importance in developing society's material base and making people's lives comfortable is the per capita production of energy, especially the electrical energy. The world average is at present only about 0.23 standard kilowatts per person. This is an extremely small amount especially when we consider that it is many times smaller in the developing countries.

Without a doubt, electrical energy is the most versatile form of energy. At present, it is obtained principally from thermoelectric power plants, which burn fuel of various types. However, in many instances it is necessary to use thermal energy directly, for example, for the work of automobile and airplane engines. In the final analysis, then, the basic index of the amount of available energy is the per capita amount of extracted fuel. The world average for crude fuel extracted per capita is about two tons (with thermal value of 7,000 kilocalories/kilogram). Of course, this figure varies widely for different countries. For example, the United States obtains 10 tons of fuel per capita, while India has only 0.2 tons, i.e., 50 times less.

We shall examine first the state of contemporary energetics, looking principally at fossil fuels (coal, oil, gas). The present yearly average for the extraction of comparison fuel is 6,000 million tons. On combustion, this yields $7 \cdot 10^6$ kilocalories/ton, which means

that the total output of energy is $42 \cdot 10^{15}$ kilocalories. Table 1 shows how this fuel is used. The figures are the approximate percentage of total fuel extraction.

Table 1

1. Transport (automobile, aviation, railroad, water), and agricultural machines, especially tractors	25-30%
2. Thermoelectric power plants, including heating systems	30-35%
3. Industry, especially metallurgical, chemical, mechanical engineering and building materials industry	30%
4. Domestic consumption	5-10%

Thirty per cent of all fuel extracted goes for generating energy at thermoelectric power plants. Thermoelectric power plants (working with an average efficiency of about 30 per cent) provide the overwhelming share of electrical energy. Hydroelectric stations provide approximately 17 per cent, while atomic energy stations for the time being provide only a small proportion. The rapid development of industry, mechanisation of agriculture and the rapid growth of the world's population all stimulate a continual increase in the extraction of fuel. Under these circumstances, it is natural to ask how long the reserves of fossil fuels will last. It is difficult to answer this question, because there are at present no theoretical grounds to estimate these reserves even approximately. Figures on explored reserves vary from year to year. Thus, in the last 30 years geologists have discovered extraordinarily large reserves of oil at the same time that many old deposits have been exhausted.

Nevertheless, on the basis of deposits uncovered and geological prognoses, there are different but roughly comparable estimates of world reserves of fossil fuels that can be developed economically. The figures from one of these estimates are given in Table 2.

Table 2

World Reserves of Fossil Fuels

(in tons of comparison fuel)

Fuel	Reserves		Exploitable Reserves	
	tons	%	tons	%
Total	12.394×10^{12}	100	3.484×10^{12}	100
Coal	11.240×10^{12}	90.44	2.880×10^{12}	82.66
Oil	0.743×10^{12}	6	0.372×10^{12}	10.68
Gas	0.229×10^{12}	1.85	0.178×10^{12}	5.11

The second and third columns give predicted geological reserves, the last two give the economically expedient yield of these reserves.

In 1970, the yield of all types of fuel listed in the table was about 6,000 million tons of comparison fuel. Thus, annual extraction is about 0.15 per cent of the reserves given in the last two columns.

The rate of increase of fuel extraction has over a number of decades been quite high (it just about doubles every 20 years).

Taking the rate of extraction in the past as a base and assuming that the rate of increase will continue the same, we can predict mathematically annual extraction in the future. We shall designate world extraction of combustible fossil fuels in 1970 $A = 6 \times 10^9$ tons of comparison fuel. We shall count time—t—from 1970, t being expressed in years. Annual extraction is then $Q = A \cdot 2^{t/20}$. We are not concerned, however, with annual output of fossil fuels, but with total output over t years from 1970, which is expressed by the integral

$$\int_0^t Q_t dt = A \cdot 20 \int_0^t 2^{t/20} \cdot dt/20 = \frac{A \cdot 20}{\ln 2}(2^{t/20} - 1) \approx 30A(2^{t/20} - 1).$$

From this we can calculate the proportion of exploitable reserves (in Table 2, columns 4 and 5) that will be extracted by timeot (see Table 3).

Table 3

t in years	Years	$2^{t/20}-1$	$30A(2^{t/20}-1)$	Yield after t years, in % of reserve
20	1990	1	18×10^{10} tons	5.14
40	2010	3	54×10^{10} tons	15.14
60	2030	7	126×10^{10} tons	36.0
80	2050	15	270×10^{10} tons	77.0

Thus practically all fuel will have been extracted in 80 years if we take the reserves given above as our base.

If we assume that further geological exploration and improvement of the coefficient of extraction will yield increased reserves, say, by eight times (it is hard to count on more than that, since deep drilling, which significantly increased oil reserves, was long ago mastered), fuel reserves will be exhausted not by 2050, but by 2110, i.e., not after 80 but after 140 years.

American scholars have made similar forecasts. According to their calculations, economically suitable reserves of fuel in the

United States will be exhausted after 75-100 years, and all potential reserves after 150-200 years.

* * *

It is not difficult to understand why the rate of fuel extraction has increased significantly over the last years. The fact is that extraction of oil from 1880 to the present day has increased quite rapidly: it has doubled approximately every 10 years. However, total oil output in the first 30 years of the 20th century was small in comparison to coal. Subsequently, extraction of oil began noticeably to approach the extraction of coal, and by 1950 equalled coal extraction (in units of comparison fuel).

The weight of oil and gas in contemporary fuel has been growing rapidly in the last decades and is now about 70 per cent, the weight of coal falling to 30 per cent. Yet world reserves of oil and gas, as we see in the last two columns of Table 2, are less than one-fifth of coal reserves. If this balance continues, these most important raw materials for transport and chemistry will be exhausted within the lifetime of the present generation. Hence, world electrical energy must be based fundamentally on coal.

Many doubt that the rapid rate of increase of fuel extraction will be maintained in the future, and in fact hold that the rate of increase may fall. It seems to me that this supposition is not entirely correct. One must suppose that the 21st century will see rapid technological progress in the developing countries. As we have seen, the disproportion in amount of fuel extracted is very large. In 100-150 years, the picture should change fundamentally, and the extraction of fuel should have, if not been equalised for different groups of countries, at the least approached toward the upper level. So over the course of time one should expect rather an increase, but not a reduction in the rate of growth of fuel extraction, measured on a world scale.

* * *

Of course, all these predictions are based on different assumptions, and they can vary within broad limits. One thing only is completely clear. No matter what the conditions, the reserves of fossil fuel will be exhausted in the foreseeable future. A real catastrophe looms over mankind—an energy famine. We, the people now alive, are thoughtlessly expending the reserves of a most valuable raw material, which will be needed by future

generations to support the production of chemicals, organic materials, detergents, and so on. Therefore, our task, especially for scientists and engineers, is to find different, new, more effective ways to supply mankind with energy. This must be done quickly, while fossil fuels still suffice for the chemistry of future centuries. It is gratifying to note that over the last 20 years such new ways have begun to be developed.

The need to move on to new forms of energy, which do not involve the combustion of fuel, is also dictated by other considerations, unrelated to the problem of the exhaustion of fuel reserves.

Modern factories, thermoelectric plants and internal combustion engines emit into the atmosphere an enormous amount of carbon dioxide as a byproduct of the combustion of fuel. We have seen how rapidly the consumption of fossil fuels has grown in the last few decades. These fuels are burned basically in combustion chambers and furnaces. This enormous extra amount of carbon dioxide is not only used by plants; it is also absorbed by oceans where carbonates are formed. The oceans are thus a powerful buffer maintaining the carbon dioxide balance in the atmosphere. However, a certain, though at present small, increase in the carbon dioxide in the atmosphere is now noticeable.

The extraordinarily rapid increase in the consumption of fuel will with time lead to a significant increase in the amount of carbon dioxide in the atmosphere. There is no danger in it for man and animal, but it could have catastrophic consequences by changing the Earth's climate after 200-300 years.

Both the rapid exhaustion in the future of resources of ordinary fuel and the danger of increasing the level of carbon dioxide in the atmosphere put to mankind the urgent problem of basing world power industry on a new principle. We have little time to do this, at most 100 years.

* * *

It is natural that our expectations should be turned first to the use of atomic energy in the form of the atomic power plants that exist now. However, the yield from atomic energy is limited by the deposits of uranium. True, since the discovery of atomic energy the deposits of uranium known to be economically suitable for exploitation have grown constantly. The problem is that in generating electrical energy, only isotope U-235 is used, and U-238 contains only 0.7 per cent of U-235. The rest of the U-238 goes into

the tailings. Atomic energy in this form will never be able to hold the dominant place in power industry.

But it has long been known that when a neutron is added to U-238 it ultimately yields plutonium, which is even more active than U-235. To do this, however, an efficient neutron source is needed. The idea of creating such a source arose in the beginning of the 1950s in the Soviet Union, and then in the United States. A proton accelerator working at 0.5-1 BeV could serve the purpose. Fast protons hitting U-238 pierce the atom's electron envelope, penetrate the nucleus and knock out 30 to 50 neutrons for every entering proton. The neutrons obtained in this fashion react with U-238 and transform the latter into plutonium. This idea has been hotly discussed in the Soviet Union and the United States down to the present day.

However, in the meantime in both the Soviet Union and the United States, a much simpler approach for using U-238 has been developed: so-called breeder reactors. Prototypes of such reactors have already appeared in the United States, the Soviet Union and France. Optimal types of breeder reactors fueled by plutonium are being developed. When an atom of plutonium fissions, about 3 neutrons are expelled. One feeds a chain reaction of fission, which fuels the electric plant. The second neutron is absorbed by the reactor's U-238 envelope and goes into the formation of plutonium, which provides a new charge for the reactor after the original charge of plutonium has been used up. Finally, the third neutron of each atom is in part lost and in part provides additional plutonium for reactors, which makes it possible to "breed" atomic reactors. This method makes it possible to use a very large proportion of the extracted uranium as fissionable material. In other words, the efficiency of the ore extracted can be raised almost 100 times. And it becomes economically feasible to develop even poor deposits of uranium, and also to extract uranium from ocean water. Although the concentration of uranium in the water is very small (5 milligrams per ton), the total reserves in the ocean are 1,000 times greater than those in the Earth's crust.

At present, the number of breeder reactors is increasing comparatively slowly (they just about double every 10 years), but after 50 years a significant part of the Earth's energy may be supplied by atomic energy.

The method of breeder reactors is in principle completely realistic, and it is only purely technological problems that still need

solution. One of their virtues is that they emit no radioactive gases except small amounts of crypton, which must be carefully removed when breeder reactors become numerous. However, there is one drawback, which is that almost all reserves of uranium and thorium will be turned into radioactive waste, which could have harmful consequences. Therefore, even when they are buried deep in the earth it is essential fully to guarantee that the waste from fission will not over the centuries poison subterranean waters. Tests already carried out on this problem give positive results, but, considering the enormous increase in the number of atomic reactors, it is necessary to undertake the most scrupulous research into the conditions of burial that will with absolute certainty eliminate any danger.

Controlled thermonuclear reaction offers mankind completely new possibilities. Its development seemed at first impossible because of the enormous amount of heat liberated and the correspondingly high temperature in the reaction zone, a temperature exceeding hundreds million degrees. These temperatures are necessary for the reaction to proceed sufficiently rapidly and to support itself. As a matter of course, the heat yield would in an instant turn the walls of a thermonuclear reactor to gas. However, physicists (so far as I know, Soviet physicists were the first to do this) have advanced the principle of magnetic isolation, which solves the problem of transmitting heat to the walls and in principle makes this process practicable. While heating a substance with a powerful current pulse, it was managed for an instant to achieve a temperature close to that necessary to start a thermonuclear reaction and to verify the action of magnetic isolation.

After the possibility of magnetic isolation had been demonstrated, scholars supposed that controlled thermonuclear reactions could be put into operation within the next decade. In many countries, especially in the Soviet Union, the efforts of many specialists were focused on this problem. However, the more research was done, the more difficulties became apparent. It is now possible to formulate the precise difficulties that must be surmounted in order to obtain a stable thermonuclear reaction.

From the beginning, two thermonuclear reactions have attracted attention. The first is the bimolecular reaction of the nuclei of gaseous deuterium. In effect, it consists of two parallel and one intermediate reaction.

$D + D = He^3 + n$	where D is the nucleus of deuterium (an isotope of hydrogen), containing one proton and one neutron; He^3 is an isotope of helium, with a nucleus consisting of two protons and one neutron;
$D + D = T + p$	T is the nucleus of tritium (an isotope of hydrogen) with one proton and two neutrons;
$T + D = He^4 + n$	He^4 is ordinary helium, with a nucleus of two protons and two neutrons; n = neutron, p = proton.

The speed of the last stage of the reaction is significantly greater than of the first two, so low radioactive tritium will be almost entirely absent in the products of the reaction.

The second thermonuclear reaction of interest to scholars is the following:

$$T + D = He^4 + n.$$

It can be carried out much more easily than the first, but it requires the synthesis of tritium, which does not occur naturally on Earth. The initial charge of tritium can be obtained in ordinary atomic reactors. Subsequently, as we shall now see, it can be reproduced in the course of the thermonuclear reaction from the neutrons that it emits. For this, the reactor must be surrounded by an envelope of the chemical compounds of lithium. The isotope Li^6 is found in lithium to an extent of 7 per cent. When a neutron is retarded in the lithium envelope, the reaction $n + Li^6 = He^4 + T$ takes place. The tritium that is formed separates and is again used in the basic reaction. Further, if a layer containing beryllium is placed between the reactor and the envelope, then a reaction takes place that produces two neutrons from one. Both neutrons react with Li^6 and two atoms of tritium form. In this case, the amount of tritium formed not only compensates for that expended in the reaction, it yields a surplus which in principle could supply new thermonuclear reactors.

In both these reactions, an enormous amount of heat is produced: in the first, one gram of gas yields as much energy as is obtained from the combustion of approximately 10 tons of coal, in the second—as much as 14 tons of coal. The reactions take place with temperatures on the order of one hundred million degrees. Under such conditions, gas is a plasma of electrons and positively charged nuclei. We will assume that the reactor works on rapidly

alternating pulses of current which heat plasma instantly. The difficulty is that plasma is stable only for a very brief time, τ, which depends on the strength of the magnetic field and the construction of the reactor. A sufficiently complete reaction is possible only if the time of reaction t is less than the time . The duration of the reaction is thus defined by the condition: $\frac{\tau}{t} > 1$. The speed of the reaction is expressed by the formula $W = kN^2$, where N is the number of nuclei in cm^3, and k is the constant for the speed of the reaction at the given temperature (100 million degrees for the reaction T + D and almost one order of magnitude higher for the reaction D + D). Hence the time of reaction $t = \frac{1}{kN}$, and the condition for carrying out the reaction is: $kN\tau > 1$. The constant k for a bimolecular reaction is, as always, proportional to the section $\sigma = \pi r^2$ of the collision of the particles, in this case nuclei. The radius r represents the maximum distance between nuclei (at the instant when they pass each other) under which the reaction can still go on.

It turned out that the section of the reaction D + D is 100 times less than of the reaction T + D, and as a result the constant k is 100 times smaller for the former than for the latter. Therefore, the numerical value of $N\tau$ for the reaction of deuterium has a magnitude of 10^{16}, and 10^{14} for the reaction of tritium and deuterium. Thus, it is much easier to carry out the reaction of tritium.

At present, a magnitude $N\tau = 10^{12}$ has been achieved in experiments, but there is reason to believe that, with time, a magnitude of 10^{14} will be achieved, which will allow the reaction of tritium with deuterium.

There are, however, three drawbacks to the thermonuclear reaction T + D. The first is the need to use the same amount of Li^6 as of tritium and deuterium. The world reserves of sufficiently rich lithium ore (and mineralised water) that have been explored are quite small, especially when it is recalled that the isotope Li^6 constitutes only 7% of lithium. If the thermonuclear reaction T + D is used as the basis of world energetics, the reserves of Li^6 in explored deposits will be exhausted within a comparatively short period of time. Lithium is a widely scattered element, and, though there is a lot of it *in toto* in the Earth's crust, it is but little concentrated. For example, it makes up from 0.001 to 0.0001 per cent of the bulk of granites, so the development of such ores is economically inefficient.

The second problem is that, in working with tritium which is radioactive it is very difficult to avoid its loss and a gradual build-up in the atmosphere. Therefore, use of a tritium reaction requires a full guarantee that there is no danger of contamination, i.e., it requires the removal of tritium from gas exhausts.

Of course, in the reaction D + D tritium appears as an intermediate product, but in this reaction tritium reacts almost instantaneously and disappears in full in the reaction T+D.

Third and finally, removing tritium from the lithium envelope of the reactor will be technically quite difficult to combine with the use of heat in the work of the ordinary reactor of an electric station. Seven-ninths of the energy of the thermonuclear reaction T+D is carried to the envelope with the fast neutrons, only two-ninths of the total energy remains in the reactor itself.

* * *

These drawbacks in the thermonuclear reaction of tritium, assuming such a reaction can be carried out, make it no more promising than the use of breeder reactors. So practical implementation of the reaction T + D can be considered only a prelude to a solution of the problem through the reaction D+D. We have seen that the difficulties in accomplishing this reaction are a hundred times greater than for the reaction T+D. Yet there is no reason to doubt that human genius will manage this, too, though perhaps at the expense of long and difficult efforts—perhaps only after decades. But, sooner or later, it will come about.

From this optimistic point of view, development and technological design of reactors for an electric station based on the reaction T + D is extremely important for the future practical implementation of the reaction D+D.

I would like to say a little more about the prospects for obtaining the thermonuclear reaction D+D. In the last 20 years, all efforts have been made in one direction. There have been no ideas new in principle. Yet there is no question that such ideas must appear. In this context, we should direct attention to a new and original idea advanced and substantiated by the Soviet scientist, Academician Basov, and some French scientists. They suggest to apply impulse heating with lasers to stable compounds of deuterium or frozen deuterium itself.

Basov turned a narrow laser beam on a deuteride of lithium. The best results were obtained with very short impulses, when the

plasma formed as a result of heating by the laser beam has no time to expand. A small discharge of neutrons was registered, which testified that a thermonuclear reaction, admittedly quite small, had taken place. According to the new proposal, the plasma requires no magnetic isolation. Though in these experiments τ is quite small, the concentration of nuclei is very high, since the plasma forms in a solid body.

Only a very small amount of the substance is brought under the laser beam. Then the laser impulse is interrupted for a short time, another small portion of the substance is brought under the beam, and so on. Thus, the arrangement works like an automobile engine, where the fuel is introduced into the cylinders a little at a time.

Recently, a group of American physicists has proposed another, very clever way to obtain thermonuclear energy by using the energy of laser beams. So far, only calculations have been published, whether or not experiments have been conducted is unknown. The idea is as follows. A spherical flow of light is directed at a spherical particle of stable deuterium or deuterium and tritium. The light ionises the upper layer of the particle and is absorbed by it. As a result, the upper layer flies off in all directions, imparting a recoil to the rest of the particle and compressing it. Calculations show that the particle is then compressed. Establishing a dependency between the recoil impulse and time (which is achieved by suitable programming of the form of the laser impulse), one can obtain almost adiabatic compression of the particle to a density 10^4 times greater than the initial density, reaching a density of deuterium atoms of up to 10^{27} atoms/cm^3. The high temperature obtained in this supports a very rapid thermonuclear reaction. According to calculations, 60 joules of laser energy can obtain 2 megajoules of thermonuclear energy. Of course, here, as in the method proposed by Basov and French scholars, the thermonuclear combustion takes place as a consequence of a rapid succession of small thermonuclear explosions, corresponding to the transformation of several dozen micromoles of deuterium under normal pressure into helium.

If the problem of carrying out a thermonuclear reaction with deuterium alone is solved, then this reaction should be made the basis of world energetics. It has a number of unarguable advantages over all other methods of supplying energy for future humanity. First, its raw materials are limitless and require no labour-consuming mining. The raw material is water, found in

unlimited quantities in the ocean; it contains deuterium in a proportion of 1/350 to the weight of hydrogen, or 1/6,300 to the weight of water. Considering that one gram of deuterium will in a thermonuclear reaction liberate heat equivalent to the combustion of 10 tons of coal, its reserves in water can be considered practically infinite. Deuterium can be extracted from ordinary water by methods already developed. To supply energy equivalent to the heat from the combustion of all fossil fuels now obtained in a year, it is necessary only to extract the deuterium from a cube of water 160 metres on each side.

A second advantage of this reaction is the absence of radioactive pollutants. He^3 and He^4, the end products of the reaction, are harmless.

* * *

Is there a limit to the use of thermonuclear energy? However strange it may seem, there is a limit, and it is connected with the overheating of the surface of the Earth and the atmosphere as a result of the liberation of heat in thermonuclear reactions. It has been calculated that the average temperature of the landmass and oceans will rise 7° when the heat from thermonuclear reactors reaches 10 per cent of the solar energy absorbed by the surface of the Earth, the oceans, and the lower layers of the atmosphere. Such a rise in the average temperature of the landmass and oceans would produce a significant change in climate and would perhaps create conditions for a world flood from the melting of the ice of Antarctica and Greenland. So it is scarcely possible to increase the yield of thermal energy to more than 5 per cent of solar energy, which would warm the Earth's surface by 3.5°. It is worthwhile, however, to obtain more precise calculations of the danger of overheating the Earth.

The Institute of Oceanography of the Academy of Sciences of the USSR undertook to make a calculation that is very difficult and has nowhere else been made: what will happen to the arctic cap and the ice of Antarctica and Greenland if the average temperature of the Earth's surface is raised several degrees? Will this increase lead only to a certain stable change in climate and to a reduction of the ice shelves in the coastal regions of Antarctica and Greenland or will heating at a certain critical temperature produce progressive melting of their ice caps?

Solution of this problem is interesting not only for our question, but also in providing an approach to the development of a theory of

the ice ages and the processes of the warming of Earth's climate. There are also many other, more limited, questions, such as for example a strict, theoretical grounding of the phenomenon of comparatively warm oases recently discovered in Antarctica.

At present, it is difficult to say precisely how much the temperature of the Earth can be raised without setting off an irreversible change in the ice cover and climate. But I think that the magnitude of 3.5° we have chosen for the liberation of energy by all thermonuclear and atomic plants is likely too high.

Let us now calculate the limits of the use of nuclear energy. As we have said already, increasing the average temperature by 3.5° means that the heat liberated from all nuclear plants should not exceed 5 per cent of the total solar radiation absorbed by the surface of the Earth and the lower layers of the atmosphere contiguous to it. Solar energy falling on the globe amounts to $4 \cdot 10^{13}$ kilocalories/second. Thirty per cent of the solar radiation is reflected from the globe into space, and a considerable part is absorbed by the upper layers of the atmosphere, etc. Less than 50 per cent of all energy that reaches the earth from the Sun penetrates to the surface of the planet and to the adjacent part of the atmosphere, i.e., $2 \cdot 10^{13}$ kilocalories/second. Five per cent of this energy is 10^{12} kilocalories/second, or, in a year, $10^{12} \cdot 3 \cdot 10^7 = 3 \cdot 10^{19}$ kilocalories/year.

According to our assumption, this is the maximum possible amount of heat energy that it is permissible to obtain from all thermonuclear and atomic electric stations. Let us compare this figure with the energy of all fuel extracted in a year (oil, gas and coal). As we have seen, the annual yield is $6 \cdot 10^{19}$ tons of comparison fuel, with a thermal power of $7 \cdot 10^6$ kilocalories/ton, which gives $4.2 \cdot 10^{16}$ kilocalories/year. Thus, we may obtain from thermonuclear energy $3 \cdot 10^{19} / 4.2 \cdot 10^{16} = 700$, i.e., 700 times more energy than we have now. It is possible that this figure is too high, and thermonuclear energy may in fact be only 500 or even 300 times greater than the energy from useful fossil fuels. Even so, this is a monumental figure. That amount of energy would, in all probability, suffice for future humanity.

* * *

Mankind has great prospects in the better use of solar energy. Every second, the Sun sends to the Earth $4 \cdot 10^{13}$ large calories. However, even in an absolutely clean atmosphere about half of the Sun's light is dispersed and absorbed, and only about 50 per cent of

the above amount reaches the Earth's surface. Clouds, dust, etc., reduce this to 40 per cent. Yet the total amount of useable solar energy remains colossal, ten times greater than what can be obtained from controlled thermonuclear reaction carried out within permissible limits.

The origin of life on Earth is connected with the appearance, first, of microscopic, and then quite large, plants, which in the process of evolution developed apparatus for photosynthesis, which by using the energy of the Sun turned carbon dioxide and water into organic substances and simultaneously liberated oxygen. The latter determined the formation and maintenance of an oxygen-containing atmosphere and also stabilised the carbon dioxide in the atmosphere. These factors taken together made possible the appearance of an animal world.

The reserves of fossil fuel owe their origin to the plant world and, to a lesser degree, the animal world. They are, in a certain sense, the accumulated solar energy of years long past. All of our modern industry is based, in the final analysis, on solar radiation. The food, both vegetable and animal, that allows three to four billion people to live and work, is obtained with the help of solar energy in the process of photosynthesis in agricultural plants, which are either consumed directly by man (as plant food) or feed agricultural livestock, which supply us with meat, milk, eggs, and so on. Man as a muscled machine is driven, with a quite high efficiency, by food energy through "combustion", not in a blaze (as in furnaces or engines), but through rather a slow, flameless oxidation in the organism. This efficiency reaches 30 per cent, that is, a magnitude of the same order as in an internal combustion engine. The efficiency of converting chemical energy directly into muscular work reaches 70 per cent, that is, almost 1.5 times greater than the efficiency of the best electric stations. There is no reason to wonder at this, since the energetics of an organism is completely different from industrial energetics and in principle allows the conversion of energy with 100% efficiency. A striking example of this is the conversion of chemical energy into light energy by fireflies.

Similar slow processes of combustion can be effected, too, in chemical systems. Fuel cells are an example, they have close to a 100 per cent efficiency in converting chemical energy into electrical. Unfortunately, so far high efficiency has been attained only in the hydrogen-oxygen cells, though no doubt in the future we will succeed in replacing expensive hydrogen with the hydrocarbons of oil.

* * *

A large part of humanity now is undernourished, and to this day there are places on the globe where famine is a frequent guest. Yet merely improving the methods of cultivating, fertilising and irrigating present arable lands so as to reach the highest possible level of production (not to mention expanding acreage sown) would supply enough and good-quality nourishment not only for the entire present population of the globe, but for many more people, too. Average yields are still low.

However, given a sufficiently high level of agricultural technology, given sufficient water and fertiliser, 15 tons of dry matter can be obtained per hectare. And some cultures such as corn, sugar cane and other tropical grasses yield up to 40 to 50 tons of dry matter per hectare. If the crop is designated for direct human consumption (for example, grains), then of the 15 tons of dry organic matter approximately 40 per cent, i.e., 6 tons, can be used directly as food for people. If the crops are meant to feed cattle, almost all 15 tons are used. However, only a small part, about 10 per cent, i.e., 1.5 tons, is obtained from agricultural livestock in the form of meat, milk, butter, fat, eggs (calculated by dry weight).

A person's optimal daily ration is about one kilogram of dry food; vegetable food should provide 750 grams, animal—250. To adequately feed 3,000 million people, given yields indicated above, would require the cultivation of 130 million hectares in all for human consumption, 180 million hectares for the maintenance of agricultural livestock, i.e., a total of about 300 million hectares, or 2.2 per cent of the Earth's land surface (not counting Antarctica). This is 4 to 4.5 times less than the amount of agricultural land presently cultivated. And today, the average individual eats much worse than the indicated norm. The average yield is at present many times less than possible. Thus, raising the general yield to high, but quite practicable, levels would make it possible for existing farmlands to feed many more than they now feed. If we have practically inexhaustible reserves of energy to develop irrigation and land reclamation, to warm seed beds and greenhouses (and to supply them with supplementary carbon dioxide), if we learn to make cheap and durable plastic covers for seed beds and soil, protective covers against loss of moisture in sandy soils, then all this will open enormous possibilities for obtaining ever larger yields and for opening areas that are now

little suited for agriculture. However, I think that our basic task is not to expand the areas sown, but to increase yields by improving the quality of agriculture, by securing sufficient moisture in the soil and by selection that will allow existing agricultural lands to provide food for a population five times greater than that presently on Earth. If the present rates of population growth persist, then mankind will increase five times over in 100 years. Thus, we are limited not by food, but by the energy needed to develop industry, in particular the production and use of agricultural equipment and the production of fertiliser, and to fundamentally improve peoples' lives.

* * *

Let us now compare the amount of fossil fuel extracted in a year (in tons) with the amount of food and fodder annually obtained (also in tons, in dry form).

At present, the world harvest is approximately $7.5 \cdot 10^9$ tons, i.e., somewhat larger than the $6 \cdot 10^9$ tons of fuel annually extracted. The calorific value of food and fodder in its dry form is about $4 \cdot 10^6$ kilocalories/ton, as against $7 \cdot 10^6$ kilocalories/ton of comparison fuel. Hence, the calorific value of the annual yield of food and fodder is about 70 per cent of the calorific value of the fuel extracted in a year. One must add to this the economic cultures (cotton, flax, etc.), the exploitation of forests, and so on.

Total annual world production of photosynthesis on land and in the oceans is estimated (very roughly, of course) at 80,000 million tons, which exceeds the annual amount of fuel extracted by about 14 times (and with a calorific value that is 7-8 times greater). Of course, these figures must be considered approximate, since it is far from easy to determine the photosynthetic product of the oceans and land not connected with man's agricultural activity. However, it is now clear that the oceans' photosynthetic product does not, in any case, exceed the same product on land, though the oceans' surface is four times greater. Let us look more closely at the productivity of forests, where one can make more definite calculations.

Total forest area is approximately $4 \cdot 10^9$ hectares—$4 \cdot 10^7 km^2$ which is approximately one-third of the dry land on the globe. The efficiency of photosynthesis in trees is quite high.

Thus, the production of photosynthesis is for northern forests 8 tons per hectare, for tropical forests, much more. This calculation is based not only on commercial timber, but also on knots, roots

and poor-quality trees. If we assume that the average weight of world growth is 10 tons per hectare, the world's forests have an annual yield of $4 \cdot 10^{10}$ tons, i.e., 40,000 million tons of wood, which is 7 times more tonnage than annually extracted fuel, and 4 times more calorific value than annual fuel production.

It is a matter of course that burning wood, which is a valuable building material and a raw material from which cellulose and many other organic substances can be obtained, is non-rational. However, combustion merely of the waste of forests would supply all the energy needed by the forest industry. Unfortunately, much of the greater part of timber growth is not used at all, but rots because of the lack of correct exploitation and the difficulties of transporting timber from the northern and tropical areas. It is necessary in the immediate future to establish care for forests and for their exploitation.

At first glance, the figures cited as to the possible use of plant photosynthesis seem quite large. However, compared to solar energy striking the Earth's land surface, they are insignificant. The efficiency of the transformation of solar energy into food and fodder chemical energy, given the high yields indicated earlier (15 tons of dry matter per hectare), is 1.5 per cent; given present average yield, it is 5 times less[1].

This low efficiency stems, first, from the fact that in early periods of vegetation, when the plants are small, leaves cover only a small part of the field, most solar energy falling on the ground, not on the plants. Conversely, at full growth, some of the plants' leaves shade others, and, basically, only the upper leaves work. This obstructs the physiological functions of the plants, and also reduces the efficiency of photosynthesis: with little light, the efficiency of photosynthesis is 10 per cent, but it falls as light increases in intensity. At high intensities of irradiation, the output of substance generally ceases to depend on the intensity of the light; speed of the photosynthetic process is determined by the activity of the enzymes, the rate of diffusion of the initial substances in the plant, and so on.

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[1] The efficiency of photosynthesis is determined by the ratio of calorific value of the harvest (in dry weight) and the amount of solar radiation per hectare, expressed in identical units, for example, in kilocalories/hectare. Biologists usually determine efficiency only in the relation to that part of the visible solar spectrum that is the active basis of photosynthesis, an energy that equals half of the entire solar spectrum. Hence the efficiency that we have adopted corresponds to a "biological" efficiency of 3 per cent.

Taking this peculiarity of the efficiency of photosynthesis into account, it would be very useful to create conditions for a balanced distribution of solar energy over all leaves of the plants by increasing the active surface area of the leaves and reducing the intensity of the light, which will result in higher efficiency. Evidently, such conditions are realised in corn fields in the two to three weeks before harvest and in sugar cane plantations for plants in their second year. The peculiarity of these cultures, as of many other tropical grasses, is that their long leaves are set at an acute angle to the stem. This permits, especially in southern areas, sun rays to penetrate deep into the thick of the crop. And the light reflected from the leaves and passing through them creates in the thick of the entire crop a balanced though not very intense illumination. These conditions make possible a high efficiency of photosynthesis, much higher than when sun rays fall directly on a solid upper layer of leaves. In the stages of development specified above, and given good agrotechnological conditions, these crops convert the solar energy that falls on them with an efficiency of 7 per cent.

This high efficiency of photosynthesis depends on a variety of conditions (shape and distribution of leaves, care for the crop and so on), not just on the mechanism of photosynthesis itself.

It turns out that the relationship between values of initial efficiency and the character of their functions is not identical for different plants. In general, however, they fall into two groups. One includes all plants of the temperate zone, the other includes the so-called tropical grasses. For the first group, efficiency at low intensity averages 8 per cent, for the second group—12 per cent, which is equal to a "biological" efficiency of 16 and 24 per cent. This fact is one of the reasons for the higher yields of corn, sugar cane and similar plants.

* * *

Thus, solar energy in conjunction with agronomic measures and selection is capable of providing mankind with food for one to two hundred years in advance even with a great increase in population.

Let us now examine whether we will also be able to obtain from the energy of the Sun a sufficient quantity of electrical energy for the needs of industry and daily life, taking into account the gradual reduction of the reserves of fossil fuels stored up over the course of many millions of years from the same solar energy. And will we perhaps be able to obtain organic substances, by purely chemical means, from solar energy outside plants?

In space flights and especially in study of the surface of the Moon (and, later, of Mars, too), solar batteries made of semiconductors are used; these batteries work with an efficiency exceeding 10 per cent. There is no doubt that in the future scientists will be able to raise the efficiency of the transformation of solar energy into electrical energy up to, shall we say, 20 per cent. In these batteries, by the way, in contrast to the situation with photosynthesis in plants, efficiency is not reduced as the intensity of solar energy increases.

In principle, given a further reduction in the cost of semiconductor materials, it would be possible to use such batteries on the surface of the earth, too, covering large areas with them. Daily, monthly and annual changes in the intensity of irradiation and, consequently, of the batteries' electrical current, could be eliminated by accumulating electricity in the form of the products of electrolysis. It would be possible to select an electrolytic process whose products would make it possible to transform their chemical energy into electrical energy with an efficiency of about 100 per cent in fuel cells or in ordinary electrical cells. From these cells we could obtain a current of constant power.

The photoelements themselves must be distributed over large areas. They can be safely sealed in plastic cassettes. It should not be more difficult to care for these "energy fields" than to care for agricultural fields.

However, I do not think that this is the optimal solution to the problem of using solar energy. For one thing, a great deal of valuable semiconductor material would be needed. There is, it is true, a possibility of obtaining some organic semiconductor materials that would be much cheaper. Unfortunately, this field is little studied, and for the time being the efficiency of batteries made of this material is quite low (about two per cent). However, one should not rule out an increase of the efficiency in these materials in the future.

All the same, I would think that we must look for other ways to solve this problem.

I have to begin with the distant past. About 150 years ago, the German chemist F. Wöhler carried out the synthesis of urea, and this was the beginning of a revolution in chemistry. Before Wöhler, chemists supposed that organic substances could be obtained only in living organisms under the action of some mystical, vital force. This view hindered the development of organic chemistry. Wöhler

destroyed this prejudice, and after a comparatively short time there began a headlong growth of organic synthesis. Organic chemistry became one of the most developed sciences, giving birth at the turn of the century to an enormous industry.

Simultaneously, organic chemistry began more and more to aid the development of biology, and the modern revolution in biology was to a significant extent provoked by chemical research, above all research into the chemistry of natural compounds. In this way molecular biology and bioorganic chemistry came into being.

In the development of these new sciences, it was discovered that chemical reactions in a living organism take place quite differently than in our laboratories and chemical factories. Thus, Wöhler was only partly right. We can synthesise in our laboratories any organic substances up to proteins, and we even begin to synthesise nucleic acids, which are the very basis of life. But the mechanism and the principles of synthesis in organisms are different than in laboratories. In plants and, especially, in animals, complex syntheses proceed momentarily, while they often demand months of work in laboratories.

And we stand again at the beginning of another revolution in chemistry, which is now provoked by biology. While our chemical industry uses high temperatures and pressures, the organism is able to carry out the same reactions at ordinary temperatures and pressures.

* * *

The primary source of energy in green plants is solar radiation, in animals—the energy produced by oxidation of food products; this energy is used for carrying out reactions in organisms and for the work of the muscles. It is stored up in the form of chemical energy in molecules of adenosine triphosphate (ATP). When the organism uses energy, ATP turns into adenosine diphosphate (ADP), which then, under the action of solar energy, is charged anew and becomes again a molecule of ATP.

Plants feed above all on carbon dioxide and water, animals on plants and animal food. In both cases, remarkably specific catalysts are used, so-called enzymes, which are enormous protein molecules with small active centres. In a great many cases, these active centres contain transvalent metal ions.

I cannot here go into the details of the mechanism of chemical reactions either in the organism as a whole or in its individual cells.

The cell is a miniature chemical-energetics factory with special shops: charging ADP, delivering substances to various zones, transporting amino acids, assembling proteins. A special "control mechanism" controls protein assembly. Preparation of parts and assembly of protein molecules surpasses in precision the assembly of an airplane. Nature has built this miniature factory with a perfection that we can as yet only aspire to in our factories. So it seems at first glance not very realistic to try to use this complex mechanism in ordinary chemistry.

But here, it seems, we are mistaken. The fact is that in the living organism everything is interconnected. Each element of the structure, even in the individual cell, must maintain this interconnection of the functions of the whole cell and even of the organism as a whole. If we want to implement any one function outside the organism, for instance, if we want to obtain a given substance, the task can be simplified. Not copying nature, but using certain of its principles, we will be able in time, in a much simpler form, to implement any chemical process that goes on in the organism. If this potential is demonstrated in reality, then chemical technology will in many respects undergo a genuine revolution.

I shall illustrate this conclusion with the example of the fixing of atmospheric nitrogen outside the organism, under conditions of normal temperature and pressure: obtaining ammonia and its derivatives from atmospheric nitrogen and water. This process was carried out by the Soviet scientists Volpin and Shilov in the last few years.

Before their work, this sort of synthesis was known only in the root nodules of legumes and in some free-living microbes, which had long and widely been used in agrochemistry to raise the content of fixed nitrogen in soil. Biologists and biochemists discovered that the process of nitrofixation is carried out with the aid of special bacteria that live in the soil or in the nodules of different legumes. Their ability to do this stemmed from the fact that these organisms had special enzymes that carried out the reaction of nitrofixation. These enzymes (as others, too) are enormous protein molecules with small free radicals that contain microquantities of molybdenum or vanadium ions. It was noted, too, that the fixing of nitrogen in plants goes on in the presence of magnesium chloride. Biochemists made a number of attempts to discover the mechanism by which these enzymes work.

The two Soviet scientists, as already noted, carried out this process outside the organism, and with a reaction time close to that of nature. Instead of enzymes, they used complex compounds of different transvalent ions.

In 1964, Volpin first reduced nitrogen to a nitride in nonaqueous catalytic solutions. In 1966, Shilov showed that ions of transvalent metals form stable complexes with atmospheric nitrogen under low temperatures; ordinarily inert, nitrogen in such conditions is quite active and able to expel water and ammonia from complexes of these metals.

It is worth noting that these complexes of transvalent metals and nitrogen turned out to be very stable. For some metals, they break up only at a temperature of about 200°C.

Adding alkaline to aqueous solutions of vanadium salts in a large amount of magnesium salts Shilov obtained by the ordinary method a friable, flaky, amorphous precipitation of vanadium hydroxide $V(OH)_2$, containing ions of magnesium and molecules of water as ligands (molecules and ions connected with a central ion in a complex compound). On the infusion of the solution with atmospheric hydrogen, this precipitant turned out to be a powerful catalyst for the formation of hydrazine H_2NNH_2, and when some conditions are changed—a catalyst of ammonia itself. The speed of the reaction was so rapid that to measure the constant of speed it was necessary to work close to the freezing point of water. In any case, this speed was no less than the speed with which nitrogen is fixed in nitrobacteria.

It should be noted that the reaction for obtaining hydrazine from molecular nitrogen and water is strongly endothermic: it requires more than 120 kilocalories per gram-mole of hydrazine. From what source can this large energy deficit be compensated? It turns out that the source of this energy is the transition of vanadium from a divalent to a trivalent state—from $V(OH)_2$ to $V(OH)_3$.

To obtain one molecule of hydrazine, four atoms of vanadium shift to a trivalent state, so that each act of reaction liberates somewhat more energy than is necessary for the formation of hydrazine from nitrogen and water. What was surprising was that the energy needed to activate the reaction was quite small—on the order of ten large calories per gram-mole, and this is the reason for the great speed of the reaction under temperatures close to zero.

In special experiments with an infrared spectrometer, Shilov was able to establish the structure of the initial groups of transvalent

metals and nitrogen in nonaqueous solutions. In the case of vanadium, it is

$$(OH)_2V\ldots N\overset{\vdots\vdots\vdots}{\equiv}N\ldots V(OH)_2.$$

In other words, in the presence of two ions of vanadium, neither the first nor the second bond in the nitrogen is broken, but rather weakened, and in compensation a quite strong interaction is established between each atom of vanadium and atom of nitrogen. After this there presumably begins the stage of simultaneous reactions, which can be written summarily in the form:

$$(OH)_2V\ldots N\overset{\vdots\vdots\vdots}{\equiv}N\ldots V(OH)_2 + (OH)_2V\ldots$$

$$\ldots V(OH)_2 + 4H_2O \rightarrow H_2N - NH_2 + 4V(OH)_3$$

In practice, it turned out that for each molecule of hydrazine formed, four molecules of $V(OH)_2$ are expended, which turn into $V(OH)_3$.

The mechanism of the reaction for obtaining hydrazine is still not completely clear. Most likely, ions of magnesium and ions of vanadium form a complex catalytic group that contains molecules of water as the ligands of this complex compound. We have already mentioned that molecular nitrogen is able to expel water from complex compounds of transvalent metals. Obviously, in this case, too, a molecule of nitrogen replaces one or two molecules of water, thereby entering into the complex compound of vanadium. As always in complexes of this sort, all its molecules are close to one another. And all the valent electrons of the different molecules entering into the sphere of the complex field are to a large degree held in common. So a quite small "heat" charge (measured in this case in calories per mole) is enough to set off a simultaneous chain of reactions, which leads to the formation of hydrazine as indicated above.

This process evidently imitates a process in a living organism (nitrobacteria). But how much simpler it is! Even at the present stage it is apparent that this unbelievably complex reaction can be carried out simply and easily. No complex enzymes are required, they are replaced by the radical of the enzymes—vanadium ions. This supports the hypothesis advanced earlier, that the complexity of biological processes is connected with the multi-functional tasks of enzymes in the living, integrated organism. When we move to a reaction outside the organism, only one function is demanded of the catalyst—to carry out the reaction. And for this, it is enough to

have only the active centres of the enzyme.[1] This is now being verified in various other reactions carried out in organisms.

But we will try to determine whether the reaction for nitrofixation has any commercial value.

Hydrazine, in and of itself, is a valuable fuel. With hydrazine, one can obtain the whole spectrum of organic compounds containing nitrogen. One should also note that hydrazine can easily be turned into ammonia. However, it would be very difficult for this process of obtaining ammonia to compete with the present, very effective method for producing ammonia salts from nitrogen and hydrogen. The latter reaction takes place under high temperature and pressure with heterogeneous catalysts. On the other hand, one must keep in mind that the current process was developed because there were no catalysts able to support the reaction for the fixation of atmospheric nitrogen at low temperatures. The higher the temperature, the less the thermodynamic yield of ammonia. Under low temperatures, the thermodynamic yield is practically 100 per cent. In order to raise the yield at high temperatures (when the catalyst can work), it is necessary to apply high pressures. Is it possible, then, with the catalysts that have now been discovered, to devise a competitive process for obtaining ammonia? At present it is not possible, since the vanadium hydroxide is not actually a catalyst in this process. In fact, shifting from a divalent to a trivalent state, and thus yielding its surplus chemical energy for the formation of hydrazine, the vanadium ions cease to work. It is necessary, therefore, to extract the hydrazine from the solution and then, with an electric current,

[1] In essence, life could not have arisen on Earth otherwise. Life could only develop from what is not alive. This means that even in preorganic nature primitive but vigorous reactions had to take place that would provide the necessary conditions for the origin of life, i.e., reactions that lead to the formation of free oxygen in the atmosphere, various organic substances and ammonia. From the latter two substances could arise the whole spectrum of compounds containing nitrogen, right up to proteins. Thus, reactions of initial photosynthesis outside the organism, which result in the formation of oxygen and organic compounds of carbon dioxide and water, and reactions forming ammonia from nitrogen and water, had to go on even before the origin of life on Earth. At the time of the origin of life, temperatures on the surface of the land and oceans could not be too high. Consequently, the reactions we have examined could take place only with the aid of catalysts. It was these catalysts that were turned in subsequent biological evolution into enzyme systems, retaining, however, the catalysts that preceded them as the free radicals of enzymes. These initial catalysts in preorganic nature were, probably, mostly ions of transvalent metals. These reflections presumably support to a significant extent the above concept.

return the trivalent ions to a divalent state. Besides the complexity of this process, a significant amount of electrical energy is required. The solution of the problem is to carry out the process of recharging the ions without the use of electrical energy, in the very process of obtaining hydrazine. We must attempt to carry out the process as it is done by plant and animal organisms, either through solar energy or through the oxidation with atmospheric oxygen of some cheap organic substances. Work along this line has only begun. If it leads to the desired results, the new process may be most advantageous. Moreover, if we succeed in doing this with solar energy, the problem of artificial photosynthesis will also have been solved.

In fact, the light stage of photosynthesis is in the final analysis defined by the reaction $H_2O + CO_2 \rightarrow O_2 + CH_2O$. This is a typical oxidation-reduction reaction, just as is the reaction for fixing nitrogen, and it requires approximately the same expenditure of energy. In principle, the reaction could proceed with the participation of the identical complex compounds.

Thus, let us assume that we will in this way be able to solve the problem of photosynthesis outside the organism and obtain good efficiency. Let us assume, further, that we will be able to raise the efficiency of the use of solar energy to 20 per cent, i.e., to make it approximately double the maximum "biological" efficiency of photosynthesis in plants. (This is, of course, only a supposition, with no experimental support at present.) Large plastic cassettes, containing an aqueous solution of initial substances. will be distributed over large energy fields. Under the action of solar energy, products of the reaction rich in chemical energy will form in the cassettes. This solution will be circulated slowly, and at corresponding substations the final products rich in energy will be removed and initial substances added. In this way energy will be continually harvested. This is, of course, only a sketch which is probably far from practicable realisation. Energy fields should be distributed in desert and semidesert areas with high solar radiation, areas unsuited for agriculture. The area of these energy fields, should, we imagine, total 10^9 hectares, i. e., about half the total field and meadow area now given over to agriculture. As an example, one can take a topographical map of Europe, Africa and the Arabian Peninsula and a small part of East Asia, where approximately one-fourth of mankind now lives. This area would require, thus, one-fourth of 10^9 hectares, i.e., $2.5 \cdot 10^8$ hectares. The

amount of desert and semidesert in this area is much more than that required.

The population of North and South America also makes up about one-fourth of the world's population. Here, too, there are deserts and semideserts. Things will be more difficult in the main part of Asia and the archipelagoes between Asia and Australia, where one half of humanity lives and where the only desert is the Gobi and the desert area of northern and central Australia. In sum, the area of all energetic fields will total 10^9 hectares, the energy yield per hectare—$3.4 \cdot 10^9$ kilocalories per year. The total world yield will be $3.4 \cdot 10^{18}$ kilocalories per year in the form of a product rich in chemical energy. As we have seen, combustion of all fossil fuels extracted in a year yields $5.6 \cdot 10^{16}$ kilocalories. Thus, use of solar radiation would permit an increase of mankind's energy resources by

$$\frac{3.4 \cdot 10^{18}\,\text{kcal}}{5.6 \cdot 10^{16}\,\text{kcal}} = 60 \text{ times.}$$

Use of solar energy, just as the use of thermodynamic energy, requires above all active scientific research. A great number of scientists are now working on the controlled thermonuclear reaction D + D, while practically no purposeful work is being done on the scientific principles of the use of solar energy.

The enormous area of the energy fields needed to collect dispersed solar energy is somewhat frightening. However, use of solar energy to synthesise food, i.e., in agriculture, likewise demands enormous areas, great investment and expenditure of labour and materials on their exploitation—and the greater the yield we want, the more capital and labour are necessary.

Use of solar energy would not overheat the Earth, i.e., there would be no changes in climate; neither would there be any danger of poisoning the Earth and its atmosphere with harmful substances. Finally, it is an eternal source of energy.

Thus, we have examined the possibility of using solar energy through photosynthesis in specially devised chemical systems outside the organism. But we can not exclude using solar radiation simply through its heat. Thirty or forty years ago, many scientists and engineers designed and even built solar machines of this sort, and they did not work badly.

However, it was clear even then that these apparatuses would not be used on a large scale. Yet the very existence of the hothouse

effect lets us raise the question of whether we may find substances that will protect "hothouses" from loss of heat into the earth and the atmosphere, the idea being that temperatures of several hundred degrees (at least for areas adjacent to the equator) could be created in these "hothouses".

It is worth noting that at the end of his life, Pierre Joliot-Curie, one of the founders of the scientific principles of the use of atomic energy, advocated the use of solar energy.

At present, it is encumbent on us to organise world scientific cooperation for the development of the scientific bases for utilising solar energy through artificial photosynthesis outside the organism. This work is extremely important, since should any practical prospects come to light, their implementation could lead to very important results both in the field of energy and in the synthesis of artificial food and fodder.

Solar energy is not just constant, it is enormous. The Sun is Earth's most powerful source of energy. Moreover, the possibility of controlling climate by cooling excessively hot areas and warming cold ones is inherent in the use of solar energy. Of course, all these possibilities are closely connected with the prospects that scientific research at the turn of the coming century will open.

I think that the search for new and enormous sources of energy (atomic breeder reactors, thermonuclear reactions, solar energy, and perhaps the energy of subterranean heat) must be conducted purposefully in all directions.

* * *

Let us imagine that the thermonuclear reaction D + D can be put into effect. From maximum use of this reaction, annually we will obtain 700 times as much energy as we now do from the energy of fossil fuels. And we will have more than ten times the energy that can be obtained, under the conditions discussed, from the use of solar energy collected in enormous fields. Would solar energy fields then be necessary?

Remember that the use of the D + D reaction will become technically possible, perhaps, after 100 years, and the construction of large numbers of such reactors will require an additional fifty years. In this time, mankind will use up a great deal of the reserves of fossil fuels and will thus deprive future generations of a useful raw material for organic synthesis and aviation fuel. This is where solar energy fields will be able to solve one of the most fundamental problems of the future.

But for this, it is necessary to solve a very difficult scientific problem—finding a way to carry out the photosynthesis reaction, i.e., to obtain organic compounds based on CO_2 and water under the action of solar energy outside the organism. We have limitless reserves of CO_2 in the form of carbonates. If we are able to solve the problem at hand, we will always be able to obtain annually 60 times more organic products than we now obtain from subterranean fossils. That is the principal goal of the solution of the problem of using solar energy.

This will save humanity forever from the danger of exhausting the reserves of fossil fuels used in organic synthesis. Moreover, the organic substances obtained from energy fields and transformed either through microbiological methods that have already been developed or through chemical synthesis can become the basic fodder for cattle. If now these processes do not have any real prospects, because our present reserves of oil are more limited than our reserves of food, they may in the future become fundamental. One must keep in mind that, raising efficiency to 20 per cent for the transformation of solar energy into chemical yield of energy fields will exceed by more than ten times the best possible yields of agricultural fields (15 tons of dry matter per hectare).

With good efficiency in the conversion of organic substances, microbiological and chemical industry will be able to obtain 40 times more fodder per hectare than at present.

* * *

An enormous abundance of electrical energy will provide the basis for obtaining unlimited quantities of any metal. The fact of the matter is that the less rich the metal ores, the more energy must be expended in extracting and concentrating them. Rich deposits will be quite rapidly exhausted (like the deposits of fossil fuels). Over the course of time, it will be necessary to use ever poorer ores, and significant expenditures of energy cannot be avoided. Having learned to concentrate poor, usually polymetallic, ores, we will be able to obtain a wide assortment of metals, since in dispersed form they are found in large quantities in the Earth's crust, in fused magma under the Earth's crust, and in the oceans.

Modern research has shown that we are on the verge of the technological and economic potential for extracting gold and, especially, uranium from sea water, though these metals are found there in insignificant concentrations. This potential has come

about as a result of the development and application of methods of sorption, in particular with the use of ion-exchanging resins, and also of various types of extractants.

The development of hydrometallurgy has already begun; it is based on the dissolution of the valuable components of rocks in a chemically active medium and the subsequent recovery of the necessary elements by sorption and extraction. Hydrometallurgy is almost ready to compete with pyrometallurgy.

It is quite possible that in the future, given a large amount of cheap energy, this "cold" metallurgy will to a certain extent replace "hot" metallurgy. And in many instances competition will become cooperation.

Electrolysis, electrothermy and plasma chemistry will be widely applied. No less serious changes will occur in metal processing, where electrochemical, spark and laser methods will come to the fore. Enormous electrical resources will make possible fundamental changes in chemical and metallurgical technology, and in the mechanical engineering and building materials industries.

At present, thorough purification of a substance, be it heat-resisting or semiconductor materials, or monomers for obtaining different sorts of polymerised material, is very expensive. Given an unlimited supply of cheap energy, all purification processes can be carried out on a much wider scale.

Stone casting for housing and road construction will be widely used. And any soil at the site of construction will be able to be turned into cast material. Much electrical energy is needed for the complete electrification of agriculture, for the conversion of all tractors and self-propelled agricultural machines to electrical energy, for the broadest development of electrified hothouse and greenhouse industry, and for all other needs of agriculture.

We have already mentioned the great potential of the methods of sorption and extraction. These and similar methods will with time be widely applied for the purification of industrial sewage, which will allow the creation of closed circuit systems at factories, will reduce the intake of water a hundred times and will practically eliminate the discharge of harmful effluents into rivers and lakes. This is the only way to finally end the contamination of waters by industrial enterprises. Factories also emit harmful substances into the atmosphere. With a surplus of electrical energy, this area, too, can be set right. A wide range of improved electrostatic precipitators and new types of filter materials can be created for

cleaning up harmful aerosols. With respect to a more difficult task, removal of harmful chemical gases such as sulfur dioxide or nitrogen oxides, emitted by factories synthesising organic compounds, new methods requiring a large amount of electrical energy must be worked out. However, all cleaning installations return at the same time a saving from the fuller use of raw material. At present, for example, so much sulfur dioxide is emitted into the air that if it could be used the production of sulfuric acid would be increased several times. We must make every effort so that in the future the air and water of our planet be clean and completely harmless.

One of the most important problems facing mankind is to make up the lack of fresh water. The progressive increase in the deficit of water will in fifty years threaten mankind with a catastrophic water famine. Efforts to solve this problem are being made now, of course, by the creation of new reservoirs and by the development of projects for the use of the waters of northern rivers in arid southern regions. The introduction of closed circuit systems in industrial enterprises is a part of this. The same method should be applied with regard to fecal water. Even today, from the energy of atomic reactors and other sources, plants are being created in some areas of the world and, in particular, in the Soviet Union, for distilling sea water.

In the future, when we dispose of ten times more energy than we do now, distilled water will be widely used, in any case on a large enough scale for irrigating large arid areas adjacent to the shores of seas and oceans (such, for example, as the western regions of North and South America, the north of Australia, the north of Africa and the southern areas of the Soviet Union adjacent to the Black and Caspian seas). When mankind disposes of reserves of energy exceeding current reserves by hundred times, distillation of ocean water will be carried out on a large scale, and this will absorb a significant portion of all energy obtained.

From this short and far from complete enumeration of needs, it is evident that in about one hundred years, with a fivefold increase in world population, it will be necessary to increase by at least 20-40 times the production of energy as against the current level; and this can be done. Of course, this demands great, joint efforts by the peoples of all countries.

All people should know and understand that their own prosperity and that of their future generations depends only on them.

CHANGES IN THE ATMOSPHERE AND SOME PROBLEMS OF ITS PROTECTION

Academician Feofan DAVITAYA

Air Pollution by Aerosols

The earth's atmosphere has become greatly polluted in recent years, measurements made in cities and industrial centres showing a considerable rise, year by year, in the content of various gases and aerosols. At considerable distances from cities and industrial centres the atmosphere's aerosol content is reduced by a factor of several hundred and even some thousand, but even there considerable quantities of aerosols are present.

It was once thought that the ever greater amount of dust in the atmosphere was the result of the growing unsystematic ploughing of land, the felling of forests, and the growth of woodless spaces, the spread of steppes at the expense of forests, and their desertification, the urbanisation, the development of transport, the power, extractive and manufacturing industries, as well as the growing meridional component in the overall atmospheric circulation during the last fifty years.

All over the world there have appeared a vast number of research papers in which various indirect methods have revealed the erroneousness of the still existing idea that air pollution is to be met only in cities and industrial centres. As a result of the circulation of the atmosphere and the turbulent currents in it, air pollution has acquired a global character, involving almost the entire troposphere.

Vast and irreversible changes in the natural environment are being caused by air pollution. The dust pollution disturbs the thermodynamic state of the atmosphere, and produces undesirable changes in climate and other associated natural conditions. The higher dust content in the troposphere can make climate warmer, this for three main reasons: the direct heating of the air by dust, which absorbs short-wave radiation; the retarding of long-wave

radiation (hothouse effect), and the resulting greater turbulent mixing in the lower layers of the atmosphere. Moreover, any increase over a definite concentration of dust in the atmosphere can lead to a cooling down of climate due to the screening of solar radiation.

Dust aerosols that settle on glacier surfaces reduce their reflective power and destroy them by speeding up the melting of ice accumulated over the centuries, this by absorbing ever greater quantities of solar radiation. Air pollution has a negative effect on vegetation, agricultural productivity, and even industrial development, especially in such advanced industries as the semiconductor, optical, photochemical and the like.

Air pollution is detrimental to human health since many of the pollutants are toxic and some carcinogenic. It should be remembered that man consumes a daily average of about one kilogram of food, two litres of water, and twenty-five kilograms of air. The choice of food and water depends on their quality and taste, but air cannot be chosen. Unfortunately no detailed research has been made as yet on the gradual and systematic influence exerted on man's health by the overall content of dust in the atmosphere and its chemical composition; the few exceptions refer to extreme pathogenic instances (pneumoconiosis, occupational poisoning by volatile substances. and some others).

Air pollution in general will probably gain momentum within the next decade unless decisive steps are taken on a broad scale. It is a question of cleaning the atmosphere of injurious admixtures and restoring the disturbed natural complex. Despite the vastness of this task, it can well be accomplished if the hypothesis of the causes of the present-day pollution of the atmosphere is correct. The following would seem the necessary measures to be taken: an end to the irrational felling of forests, reforestation of steppeland and mountainous areas; creation of field-protective forest stands; recovery of desertland so as to create productive soil protected by green shelter belts; creation of parks and green spaces in cities and villages, with rationally selected kinds of vegetation extensively used; introduction of a system of land cultivation that will prevent wind erosion.

The restoration of destroyed vegetation cover and its further improvement will solve another problem of our civilisation, which may arise in the immediate future, i.e., the lack of atmospheric oxygen, thousands of millions of tons of which are consumed

annually. We all know that the vegetation cover plays an important part in restoring the oxygen in the atmosphere through photosynthesis. So vast is the oxygen content of the atmosphere that its ever growing consumption has not yet affected the composition of the air. However, the inevitable and ever growing use of oxygen in coming years may, as we shall see now, create a shortage of it. Vegetation, which "operates" in a close cycle in the global system of the biosphere, will not add any free oxygen, but may intensify the physico-geographical process.

Meteorological offices in all developed countries, including the USSR, have in recent years been making a detailed study of air pollution in industrial centres.

To counter industrial pollution of the atmosphere, the height of factory chimneys has been increased in a number of countries, this on advice from meteorologists. This measure has proved useful because higher chimneys mean greater wind speeds, and concomitant turbulent mixing. Besides, such structures are cheaper than other measures to protect the atmosphere. In some countries, calculations have been made of the advantages accruing from higher smoke stacks: the difference in the cost of high factory chimneys and purification installations is multiplied by the total number of industrial enterprises, this revealing tremendous savings. In fact, however, this approach means self-deception, not a solution of the problem. By removing pollutants from a specific community, high factory chimneys pollute areas hundreds of kilometres away, while this particular community is polluted by industrial emissions from adjacent areas. Besides, industrial air pollutants settle on the ground and then rise into the air time and again, thus continually increasing atmospheric pollution. Minute admixtures of smoke and gases are constantly suspended in the atmosphere; periodical washing of the air by rain makes it relatively clean only for short periods, which is why the self-cleaning of the atmosphere should be understood only in a conventional and limited sense, while higher factory chimneys is nothing but palliatives.

Clean air in urban areas requires a decrease of and ultimately an end to the emission into the atmosphere of vast quantities of smoke and other products of combustion by industry, transport and domestic devices.

What is called for in the foreseeable future is the construction of stackless factories operating in closed technological cycles, with the

full recycling of all industrial waste. Present-day science and technology makes it possible to produce high-grade food and textiles from the smoke and gases that are being emitted into the atmosphere and poison it.

As we all know, living nature has achieved the highest degree of organisation in the world. Nature operates without any waste products. What is rejected by some organisms provides food for others. The organisation of industry on this principle—with the waste products of some branches of industry providing raw material for others—means in effect using natural processes as a model, for in them the resolution of all arising contradictions is the motive force of progress.

The refashioning of industrial processes thus acquires tremendous importance at the present stage of human activities, not only in keeping the atmosphere free of harmful pollutants but in maintaining the gas composition of the air at a constant level.

Other Kinds of Pollution

The following may also be conventionally included among factors of atmospheric pollution: the increasing of the electromagnetic field and changes in the gravitational field; the increase in the vibration and noise background with the extreme values exceeding the permissible levels; the decrease in ultraviolet radiation (by about 30 per cent in the open air) as a consequence of air pollution by hard and liquid aerosols. This decrease is aggravated by people spending most of their time indoors—at home, at work, in transport vehicles and so on.

To all this might be added the hypodynamia so characteristic of our times, as a result of an insufficient physical activity connected with the use of present-day technology, and also of the high nervous stress created by the rate of present-day life.

Industry today consumes vast amounts of electricity produced at thermal, hydroelectric and nuclear power stations. Energy is transmitted along high-voltage lines, thus increasing the electromagnetic field. The intensity of field varies depending on the voltage applied, but given a tension of 500,000 volts typical of modern transmission lines the background of the electromagnetic field exceeds the permissible level in a two-kilometre zone along the entire length of such lines.

Another area calling for detailed study is the use of electric transport of all kinds in cities, and especially the replacement of

automobiles by electromobiles. Experiments in this field are being conducted in all industrially advanced countries, the solution of this problem being considered of great significance in abating air pollution. However, it may prove that one kind of pollution will yield place to another.

The creation of territorial-industrial complexes and the concomitant concentration of production leads to large numbers of people being concentrated in limited areas, this calling for the construction of high-rise buildings both for industry and habitation. Using lifts people ascend and descend hundreds of metres, thereby substantially changing the effect of the gravitation field on man, and of the atmospheric pressure that goes with it.

The operation of plants, motors and engines of various kinds, and high speeds of traffic create an excessive background of noise and vibration. The vibration background may also be increased in some measure by the microseisms caused by the overall impact of present-day industrial enterprises on the earth's crust. This is a problem that calls for special study: people come into contact with vibration sources with frequences of 10 to 12 cycles per second, lengthy exposure to which is in excess of permissible standards.

Noise levels in streets in big cities now reach 80 decibels, sometimes even 110 decibels, which exceeds the highest permissible standards. It should be remembered that 130 decibels is considered a dangerous threshold, beyond which the hearing is damaged. During the last decade, the mean noise level in big cities has risen by 10 to 12 decibels, reaching 40 to 50 decibels. There have been forecasts that this level will rise by 1 decibel yearly unless the necessary steps are taken.

Data show that normal functioning of the human organism may be impaired by lengthy exposure to strong electromagnetic and acoustic fields, by frequent changes in the gravitation field, and by strong vibrations.

The cumulative impact of various unfavourable factors of this kind intensifies anomalous processes and leads to various pathological phenomena that sometimes cause highly dangerous illnesses. This is not only a medical problem but a socio-economic one as well.[1]

The rising temperature of the environment is also a factor of air pollution, especially in big cities, in many of which the mean

[1] For more details see G. Tsaregorodtsev's artide on p. 126.

temperature of the air has for many years stood between 0.5°C and 1°C higher than in adjacent localities. In some cities, the difference is almost 2°C. As a rule, this temperature rise in big cities is greater in summer and lower in winter. The formation of such heat islands stems from a number of causes, of which the following are the most significant; the lower expenditure of heat on evaporation in cities—although precipitation is higher there, it rapidly finds its way into the sewerage system, and plant life is insignificant; the lesser velocity of wind as a result of the tall buildings there; the lower effective radiation of the earth's surface as a consequence of the absorption of long-wave radiation by hard and liquid aerosols; the increase in artificially produced energy.

Thermal pollution is of global significance among the indirect factors of the change in the atmosphere's natural characteristics. In this respect, the cities of today can provide a model of possible global climatic changes brought about by man's activities. There are grounds to believe that atmospheric pollution by industrially produced aerosols and gases will become stabilised or reduced within the next few decades as a result of measures taken. At the same time, the artificial production of energy will grow. At present its magnitude for the whole planet has been estimated at 0.01 per cent of the energy received from the sun, but it is showing an annual growth of about 6 per cent, with prospects of a further rise in the foreseeable future, which means that the time is not far off when artificially produced energy may prove a substantial supplement to solar radiation.

The Problem of Free Oxygen

For a lengthy geological time, the earth's atmosphere remained constant in respect of its gas composition; at least, it was constant during the Quaternary Period. However, its carbon dioxide content has risen over the last few decades.

The origin of free oxygen has not yet been revealed, with most scientists holding that at least its greater part has been a product of terrestrial and marine vegetation. In this, a dynamic balance has been established in the biosphere: no matter how much oxygen is isolated (mainly in the process of photosynthesis and also from the photochemical decomposition of water vapour in the upper layers of the atmosphere) the same amount is absorbed through respiration, decomposition and by the numerous oxydising

processes continuously taking place in the environment. A mere 0.00007 per cent annual excess of free oxygen isolation over its consumption could have led to its total amount becoming doubled only during the present, Quaternary Period of the earth's history. A 0.003 per cent oxygen decrease a year would have led to its almost complete disappearance during the same period.

Free oxygen has also been used for artificial combustion since the time man emerged from his natural environment, and learned to produce fire. This process has not been made up for by the release of oxygen during man's productive activities in the same way as the oxygen consumed in nature is replenished. The additional consumption of oxygen as a result of the development of modern civilisation and the rapid growth of all types of industries has reached vast proportions.

It is common knowledge that a fall in the partial pressure of atmospheric oxygen by one-third leads to oxygen deficiency, a decline by two-thirds threatening lethal consequences. If we accept that future consumption of oxygen will remain at the present level, i. e., that its annual depletion will stand at 10,000 million tons, then two-thirds of the total amount of free oxygen in the atmosphere and hydrosphere will be used up in a little over 100,000 years.

If the annual increase in the present consumption of oxygen is allowed to stand at only 1 per cent, a period of about 700 years will suffice for it to fall to a critical concentration level. If such consumption goes up by 5 per cent a year, that period will fall to 180 years, and to 100 years if consumption goes up by 10 per cent.

It may be asked how real the prospect is of an annual increase in oxygen consumption by an average of 1,5 or 10 per cent. The reply to that question depends on world fuel production, whose course is shown in the table on page 106.

As can be seen from the above figures, the rate of increase in the extraction of coal as against petroleum and gas shows a decline, although coal reserves are enormous. As for petroleum and gas, their extraction has risen sharply during the last two decades. Even if the annual growth rate for the extraction of these types of fuel is stabilised, it still stands at a fairly high level (about 10 per cent). Of course, the rise in oxygen consumption is the same as for fuel extraction.

Judging by the above figures, the rise in oxygen consumption by an average of 10 per cent for all kinds of fuel seems quite realistic.

World Fuel Production (round figures)

Kind of fuel	Years				Annual increase during the periods (per cent)		
	1940	1955	1958	1967–1969 (1969 for USSR; 1967 for rest of world)	1940–1958–	1958–1967/69	1955–1967/69
Pit and brown coal (million tons)	1,200	—	2,430	2,900	5	2	—
Petroleum (million tons)	310	—	910	1,650	10	8	—
Natural gas (000 million cubic metres)	—	390	—	850	—	—	9

Moreover, we should bear in mind not only the present growth rates of industry in developed countries, but also the fact that the developing countries are beginning to follow their way.

Thus, any direct extrapolation of present-day conditions into the future will lead up to the conclusion that mankind is constantly modifying its environment. It is common knowledge that each new geological era was shorter than the one it has succeeded. While the Archean Era, the most ancient, lasted 900 million years, the Proterozoic Era that followed it lasted 600 million years, the Paleozoic—325 million years, the Mesozoic—115 million years, while the Cainozoic Era has been lasting 70 million years. However, the Cainozoic Era will also come to an end, this process being accelerated by man, that acme of creation, who has appeared during the last million years.

Though these concepts seem indisputable, the above calculations and extrapolation of present-day conditions into the future do not seem to be founded due to the following reasons.

The known reserves of combustible raw materials are insufficient for two-thirds of the free oxygen in the air to be consumed. Prospected coal reserves to a depth of 1,800 metres have been estimated at 14,947,400 million tons, natural gas at $180\text{-}200 \cdot 10^{12}$ cubic metres and oil at 400,000 million tons. In terms of oxygen

consumption, all this provides a total of 29,721,800 million tons, or 0.5 per cent in volume. However, this argument is not very convincing. In the first place, estimates of geological reserves may change by several orders in the passage of time. It has been calculated that about $6 \cdot 10^{15}$ tons of organic carbon lie below the earth's surface, an aggregate whose combustion would require ten times as much oxygen as the atmosphere and hydrosphere contain. Secondly, some new fuel may appear within the next few decades, which will call for more intense oxygen consumption than is required for coal, oil or gas. Another and more cogent argument is the power of human intellect, for it is hardly possible that mankind will follow the pattern set forth above, and will surely preserve the stability of the gas composition of the earth's atmosphere. However, the time has come for measures to be envisaged and for their systematic implementation to be launched. That should in no way be taken to mean that the development of the productive forces should be slowed down and that man's creative activities should be restricted. That would be not only impossible but even inadvisable. Efficacious means should be sought to utilise energy sources that do not require any consumption of oxygen and do not increase the carbon dioxide content of the atmosphere. Though nuclear energy solves that problem, the wastes from its production present no less danger to the biosphere than a change in the atmosphere's gas composition.

One can consider most promising the utilisation of solar radiation and its efficient conversion into various kinds of energy. Other roads of mankind's energy re-equipment do not eliminate the problem of a negative effect not only on the biosphere but on nature as a whole. It has frequently been pointed out in scientific literature that, given the present-day rates of increase in the production of artificial energy, the amount of heat emitted in various industrial processes will, in less than 100 years, reach a magnitude comparable with the amount of energy our planet receives from the sun. That cannot but lead up to a substantial overheating of the earth, with all ensuing consequences: glaciers will melt away and the level of the World Ocean will go up by 64 metres. The climatic and water regime of the terrestrial surfaces will change entirely. However, all these consequences can be avoided if the necessary measures are taken in good time.

Vast importance attaches to the creation of industries in which material production will absorb carbon dioxide and emit tens and

hundreds of billions of tons of free oxygen in the form of industrial waste. As pointed out above, the great contradictions arising between man and the rest of nature can be resolved through the organisation of industry in closed yet developing cycles, in the same way as the substance-energy cycle is progressively effected in nature.

The Social Aspects of the Problem

The protection of the atmosphere against emerging changes is not merely a scientific and technological problem. Human activities tend towards boundless development, yet though that process should be encouraged in every possible way, it should be guided along an optimum direction. The ever growing creation of material values is accompanied, on the one hand, by the expansion and modernisation of industry, and, on the other, by the latter's spatial concentration. Cities are growing apace to form conurbations, which, in their turn, are showing a trend towards expansion. The spatial concentration of industry is economically advantageous because it encourages commodity production. Suggestions have been made to expel industry from the cities, something that is unfeasible in many instances. Besides, industrial development is unthinkable without a working class, engineering personnel, schools and universities, research institutions and theatres, hospitals, governmental and managerial institutions and without modern transport and other means of communication, and many other things that go to form the infrastructure of present-day cities.

The uncontrolled development of this process leads to vast sprawling cities that are inconvenient to work and live in, as is exemplified by many developed capitalist countries. Smogs and other phenomena resulting from photochemical interactions are common nowadays in New York, Los Angeles, Tokyo, and central Rome, where there is a shortage of oxygen during certain hours of the day in calm weather. The situation will become general unless the necessary steps are taken, based on an optimum and long-term social strategy in the economic development. Instead of dispersing industry outside cities, the necessary conditions should be established within the latter, this calling, in the first place, for the construction of purification plants at factories and then going over to closed industrial cycles. The neutralisation of exhaust gases from automobiles and other transport vehicles is just as urgent.

Important among the measures required to clean the air of injurious admixtures is the extensive planting of greenery in factory shops and yards, in streets and city squares, and the planting of parks, gardens and tracts of forest lands both within and around cities.[1] USSR sanitation standards demand that there should be no less than twenty-five square metres of greenery for each urban dweller, plant species to be selected according to their ability to absorb harmful admixtures from the atmosphere. In this connection various kinds of plants differ greatly, the amount of admixtures they can absorb varying within a very wide range.

All this requires extra expenditures, which will of course affect the cost price of industrial goods. That is why the implementation of such measures is possible only in conditions of state planning. At all events, it means lower profits, which, in conditions of private enterprise, is made up by greater exploitation of the working people, this in turn exacerbating class contradictions in capitalist countries.

In a socialist society it is the state that assumes the main burden of expenditures on environmental protection. In the Soviet Union, substantial results in improving the environment have been achieved in big cities such as Moscow, Leningrad, Kiev and Baku. Smoke traps, air filters and sewage treatment installations have been built at many big industrial enterprises, where effective systems for the re-use and recycling of water have been set up. The area of greenery per inhabitant of Kiev is 25 sq. metres (which is within the standard); in Moscow, that area is 45 sq. metres.

The adoption of a complex of measures in Moscow, for instance, has considerably lowered the amount of admixtures in the air in the last few years: dust has been reduced by 50 to 60 per cent, sulphur dioxide by 60 to 70 per cent, carbon monoxide by 70 per cent, and so on. The Moskva River, which flows through the capital, has become much cleaner and is now stocked with fish, as is illustrated by the number of anglers to be seen along its embankments. It has been generally noted that Moscow is one of those rare cities where a white shirt will remain white throughout the day. Moscow's

[1] It should be noted that the present-day level of atmospheric pollution leads to the amount of dust in the atmosphere varying considerably in different parts of a big city: a cubic centimetre of air in the industrial area contains several millions of hard and liquid particles with radiuses of fractions of a micron or less. The dust content in business quarters is reduced by a factor of several dozen and in parks by a factor of several hundred.

industries are developing and the number of automobiles of all kinds is constantly increasing, yet the environment is becoming cleaner and healthier.

The common efforts of scientists working in different fields of knowledge, both natural and social, are playing an ever greater part in the solution of environmental problems in the USSR. For instance, 24 research institutes and higher schools took part in drawing up the appropriate sections of the complex plan for the economic and social development of Leningrad for 1976-1980. The Presidium of the Ukrainian Academy of Sciences has approved a program of work on the complex problem of "Science and the Cities", in which many institutes under that Academy are taking part. The program includes a corresponding plan of research work and its practical implementation. "It is first and foremost a question of drawing up and introducing effective scientific recommendations designed to create new or modernise existing technological processes, and of reducing levels of noise, vibration, the influence of electromagnetic fields and other injurious changes in man's environment", wrote K. Sytin, Vice-President of the Ukrainian Academy of Sciences. An automatic system for the control of air pollution in cities has been developed at institutes under the Ukrainian Academy. It is to be introduced in Moscow, Leningrad, Kiev and other industrial centres.

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Air pollution control cannot be effected within the framework of national programs alone, for the atmosphere knows no state boundaries. Polluted in one country, the atmosphere can cause economic damage in other countries whose inhabitants have to breathe such contaminated air.

In conditions of intensive international trade the overhead expenses on environmental protection should be approximately the same for each type of commodity produced. This refers first and foremost to the atmosphere, the World Ocean, and inland waters (internal seas, lakes and reservoirs) including rivers running through more than one country. That is why the protection of the atmosphere and other resources of nature calls for multilateral international agreements and their strict implementation.

LAND RESOURCES AND THE PROSPECTS FOR THEIR USE

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Soil as a variety of natural resources has a number of specific features. It is the product of the prolonged biological transformation of rock. The conditions in which present-day soils were formed partly disappeared for ever and partly changed in a radical way. Soil is an extremely valuable property which has a tremendous role to play in the formation and history of national culture. Together with plants and animals it constitutes one of the most important components of the biosphere and forms part of the mechanism by which they function normally. Unlike fresh water or vegetation, soil is a non-renewable resource. Artificial creation of new soils where the old ones have been destroyed is possible, but complex and expensive. As distinct from other non-renewable resources (oil, gas, metals, ores), however, soil, if used correctly, does not disappear or disperse, but gives even greater yields.

When the land is tilled in a rational way the soil becomes "cultured" and acquires features which are not present in natural soils. But very often the application of the mass technical means of influencing them nowadays runs contrary to the laws of the life and dynamics of the soil. Soils are exhausted and degraded, if used improperly; they acquire negative features, become disaggregated, or disappear completely (erosion, dust storms, salinisation and petrification).

In the foreseeable future the planet's land resources will play an increasingly important role in agriculture, forestry and the water economy as a basis for the production of the necessary biological matter. The soil resources of our planet are not infinite, however. This is why effective use of available land and its conservation as a component of the biosphere is a vital problem of our age.

The Planet's Land Resources

With the compilation of soil maps of the world, which were first produced by such Soviet scientists as V. Dokuchayev, K. Glinka and L. Prasolov, it became possible in the 1940s to make the first analysis and assessment of the use made of the planet's land resources. L. Prasolov (1945) and later the same scholar and N. Rozov (1947, 1949) were the first to compare the area of the main types of soil and the extent of their agricultural development. They showed that in the 1940s about 10 per cent of the planet's land was cultivated.

Some 40 per cent of the world's agriculture was concentrated on four soil types: chernozems, dark prairie soils, grey forest and brown forest soils. On average, from 26 to 35 per cent of these soils was under cultivation. Today the area of such soils under the plough is between 5 and 10 per cent higher: only 6-13 per cent of the red, alluvial, chestnut, cinnamonic and podzolic soils are cultivated, while the figure for the remaining types of soil (grey, savannah, desert, and mountain soils) is 2-4 per cent and less. During the last 20 or 25 years the coefficient of agricultural use (CAU) has increased by 1-2 per cent. The overall picture of cultivation level of various types of soil, however, remains the same as it was. Low-fertility soils (podzols, red soils) and soils found in unfavourable natural conditions (subpolar soils, soils in tundra zones, deserts, mountains) have been cultivated very little.

In Latin America, Australia and Africa the CAU is low even for fertile soils. Throughout the world, but especially in Asia, unused lands are situated in arid deserts, semideserts, and savannahs (which cover up to 30 per cent of the landmass), where artificial irrigation and melioration are required for soil desalinisation and reduction of high alkalinity. From what we have said it is clear that use of soils for agriculture should increase through melioration and the transformation of low-fertility soils in those regions whose natural conditions are considerably less favourable than those in regions developed previously.

Soviet scientists carry out research on the planet's soil cover in cooperation with UNESCO, FAO and the International Society of Soil Science. A great deal of new data has been gathered. The picture of a general shortage of land resources in the world is borne out by this data, however. FAO experts have calculated that from the point of view of agriculture the land resources of the world are

not very favourable in the present geological era and up to 70 per cent of them consist of relatively low-productivity areas.

General Assessment of the World's Land Resources
(per cent)

Situated			
in extremely cold climate	20	thin-solum soils	10
in too arid climate	20	Covered by agricultural crops	10
on too steep slopes	20	Covered by pastures, meadows, forests	20

FAO data show that the area of land in the world which is potentially suitable for agriculture comprises about 3,200 million hectares (32 million square kilometres). But there is reason to believe that twice this area of land can be used for agriculture.

At the present time about 1,500 million hectares (15 million square kilometres), i.e., one half of the total area suitable for agriculture, has been ploughed up and put to use. This is the best land in the world. Thus between 10 and 11 per cent of the land is under cultivation and the total area of land used in agriculture (pastures and hay fields make up about 18 per cent) comprises some 29 per cent of the earth's land surface.

Area of Agricultural Land on the Planet (hectares)	Relative Cultivation (per cent)	
Area of the landmass. . 14.8×10^9	Total 10-11	India 30.1
Including:	Europe 31	USA (including
Arable land . . . . . . 1.5×10^9	South-East	Alaska) . . . 14
Meadows, pastures 2.6×10^9	Asia 16	China 8.2
Forests . . . . . . 4.06×10^9	Africa 9	Canada 2.4
	South America . .4	Australia 1.2
	Java (Indonesia) . 70	Brazil 1.1

If one includes productive forests about 60 per cent of the land is used. FAO experts believe that it is possible gradually to double the total cultivated area, increasing it to 20-25 per cent. This is, however, a complex task which will entail considerable difficulties. Vast capital investments will be required in melioration, and work on the development, cultivation and use of new land will have to be undertaken. Expenditure on such measures in the countries of the West is now on average between 20 and 25 times as great as it was in the past.

The need for new land to be brought under the plough is dictated by population growth (it doubles every 30 to 35 years), increase in the population's demand for food and materials of biological origin, the growing losses of cultivated land due to erosion, salinisation, and industrial and urban construction, and the comparatively low average level of crop yields, especially when calculated per head of the population.

Losses of land resources in the world have assumed vast proportions—some 20 million square kilometres, which is more than the present cultivated area of the planet (15 million square kilometres). Every year between 5 and 7 million hectares of land falls out of use. Losses are caused mainly by the construction of towns and factories, erosion and salinisation. According to H. Bennett and J. Dorst, erosion of soils has destroyed about 430 million hectares of land. The United States loses up to 800,000 hectares a year due to construction and erosion. About 60 per cent of the USA's land reserves require melioration, protection and restoration of productivity. France has lost up to 500 million hectares of land due to the construction of towns and enterprises alone, whilst in Madagascar eight-tenths of the surface has suffered from severe erosion. To this must be added changes caused in soils by the wastes from cities, industry and agriculture (about 5,000 million tons of minerals, 32,000 million cubic metres of industrial water, 250 million tons of dust, 70 million tons of toxic gaseous substances, excrement and pasturage for 3,000 million head of cattle).

Experts in the West believe that by the year 2000 agriculture will have lost another 650-700 million hectares. And if the present rate at which agricultural land is lost continues, its area in a hundred years' time will be one-third of the present area. This plundering of land resources is extremely worrying and should be dealt with immediately.

The clearly marked tendencies of irreversible degradation of the soil and loss of land resources in world agriculture, as well as the cost and difficulties of developing new land, make it especially important to preserve the cultivated lands and obtain a radical increase in their productivity. There are numerous ways of increasing crop yields and simultaneously protecting and preserving cultivated soils from degradation: soil-protective agriculture, terracing and contour strip-cropping on slopes, irrigation (supplementary and basic), drainage and chemical

melioration of salined soils, control of the water regime of waterlogged soils, liming of acid soils, large doses of and optimum correlations between nitrogen, phosphorus and potassium fertilisers, new, high-yield plant varieties resistant to disease and pests, repeated harvests of stubble crops, chemical and biological protection of plants and a high level of mechanisation in agricultural production. Meanwhile, the average harvests of cereal crops and rice are still low—13-15 or 20-30 centners per hectare.

The experience of European countries shows that liming of acid soils, melioration, large fertiliser doses, new varieties of cultivated plants and a high general level of cultivation have enabled agriculture to develop at a considerably greater rate (4-5 per cent; 100 per cent increase every 18-20 years) than the rate of population growth (2.5-3 per cent; 100 per cent increase in 30-50 years). The growth of cereal crop yields during the last two or three centuries is indicative of the vast internal reserves available to increase yields on cultivated lands, provided that agricultural production is completely modernised and the level of general and agrotechnical land cultivation is raised.

In 1968 world agriculture produced 332 million tons of wheat with an average harvest of 14.6 centners per hectare from a sown area of 227,546,000 hectares. Each year the world produces about 1,179.5 million tons of cereals, including rice and maize, which is about 487.3 million tons more than the annual production in the period from 1948 to 1952. During this same time the production of oil-bearing crops and sugar doubled. The per capita production of cereals is still low (between 300 and 500 kg). In the next 30 to 40 years harvests should be doubled and even trebled. The experience of Mexico and India shows that if new varieties of cereals are used and agrarian reforms carried out, it is possible to increase the rate of growth of productivity of cultivated lands. Nevertheless, there is still a need for bringing new lands under the plough, since it will be necessary to compensate for the inevitable losses of arable land due to population increase and the general growth of industrialisation and demand in the world. It should also be remembered that all forms of capital investment in the soil and farming must be increased to secure greater harvests.

The 34 per cent growth in agricultural production between 1951 and 1966 was accompanied by an increase in annual expenditure on tractors—63 per cent, on nitrogen fertilisers—146 per cent and on pesticides—300 per cent. In planning the growth of agricultural

crop harvests this empirical proportion must be borne in mind; in relative magnitudes it can be represented in the following form: 1:2:5:10, where 1 is the growth of agricultural production, and 2,5 and 10 represent the necessary average increase of investment in tractors, fertilisers and pesticides respectively. Let us analyse the probable need for additional areas of arable land in the world. In present-day conditions about 0.1 hectare of land (housing, transport, power lines, industrial and cultural services, etc.) is used per head of the population in the USA. Each year the planet's population increases by between 2.5 and 2.7 per cent, i.e., between 75 and 80 million, and in the future it will increase by between 100 and 120 million. From this it follows that indirect losses of land resources alone caused by the current population growth comprise 7.5-8 million hectares annually and this will increase to 10-12 million hectares by the end of the century. On average 0.4 hectare of arable land per head of the population is used for producing food and other biological matter. This means that if the present average harvests remain stable, it will be necessary to develop an additional 20 million hectares of new land annually; by the end of the century this figure will have reached 25-30 million hectares per year. Finally, losses of land due to water-caused erosion, deflation, salinisation, pollution, etc., are estimated at not less than 5-6 million hectares per year and will probably reach 10 million per year by the end of the century.

Thus the probable annual demand for additional development of soils for agriculture (if the present harvests are maintained) will be between 32 and 34 million hectares in the 1970s, between 45 and 52 million hectares at the end of the 1990s or 40 million hectares on average. During the next 30 years it will amount to 1,200 million hectares. If one recalls that at present 1,500 million hectares are cultivated, the total of 2,700 million hectares taken in conjunction with probable losses (700 million hectares) faces man with the prospect of exhaustion of the land which is potentially free for future development. Obviously this position dictates the need for a rapid increase in production by at least 100-200 per cent from each hectare of arable land.

If the average productivity is doubled, the average demand for arable land will be 0.2 hectare per head of the population. Hence with a population of 7,000 million the required area of arable land will be about 1,400 million hectares, i.e., about as much as is cultivated at present. An overall doubling of the average harvest

can, however, only be achieved in 30 years time. As we have said, losses of agricultural resources will constitute 700 million hectares in this period. But the requirements of the growing population will increase at the same time. So to compensate for these losses and to meet the needs of the population it will be necessary to develop at least 20-25 million hectares of new land annually before the year 2000. The balance of mankind's needs for arable land by the year 2000 will be as follows: basic area—1,400 million hectares; losses—700 million hectares; compensation of losses—700 million hectares; total—2,800 million hectares. This figure corresponds to the existing potential reserve of land. At the same time it becomes clear that if the productivity of agricultural crops is not doubled or trebled, there may be a shortage of arable land and agricultural products at the start of the next century. So the question must now be raised of increasing the average productivity of cultivated land by a factor of 3 or 4. At the same time it is pertinent to consider a radical reorganisation of the very methods and technology of agriculture and obtaining biological products. Obviously the food resources of the hydrosphere, synthetic products of various kinds and industrial methods of agriculture such as hydroponics should be developed as new resources and sources for obtaining biological products, food and raw materials. This is all the more essential since the biosphere cannot function normally, if the soil covering is destroyed.

The planet's soils were created over millennia in conditions which no longer exist today. Errors by man bring about their destruction in but a few years. More often than not the situation is difficult or impossible to correct. So in recent years national scientific centres for the study and development of soils in various countries have been carrying out planned research into the processes of soil degradation, methods of preventing these processes, and the restoration and improvement of unfertile soils.

The soil cover does more than simply serve the needs of plants in creating phytobiomass. The soil and vegetative covers as components of the biosphere act as a planetary regulator of the composition of the atmosphere and the continental waters, an economical distributor of energy and the substances combined in chemical compounds which are essential for the exchange and cycle of elements in nature, and for man's normal development.

The biological productivity of the earth depends on the existing functioning of organisms and the soil cover in the biosphere. As

long as man does not interfere with the biosphere it remains a self-regulated system producing biomass and regulating the composition and properties of soils, the hydrosphere and the atmosphere. As man has interfered in the biosphere through agriculture, forestry, the exploitation of water resources and the obtaining of biological products, the biosphere and its components—biogeoceonoses, the water regime, soils and organisms—must be controlled in an organised and scientifically-based manner. The greater the volume of production (harvests), the better should be the methods and techniques of controlling ecosystems. Mistakes in this field may have disastrous consequences. Meliorated land having fertile soils, high-yield plants and intensive techniques—this is the highest level of organisation of a cultural agrobiogeoceonosis and a way of protecting and improving the biosphere.

The Land Resources of the USSR

The study of the land resources of the Soviet Union—the world's largest state, which contains almost one-sixth of the total land area, is not yet complete. At the moment a land cadastre is being compiled. The republics and regions have detailed soil maps of various scales and register their agricultural land, but do not yet have at their disposal detailed maps of agricultural land and their comparable assessment on a nationwide scale. The figures from a survey made by the Ministry of Agriculture of the USSR present the following picture of agricultural land:

The Land Resources of the USSR (millions of hectares)

Territory	Area	Territory	Area
Landmass	2,231	Forest	770
All agricultural land	606	Shrubs	37.4
Of which:			
		Marshes	115.5
Arable land	218	Under water	90.8
Perennial plantations	4.5	Buildings, roads, etc.	17.4
Hayfields	47	Sand, ravines, glaciers and other areas	249
Pasture	327		

The soils and land in the Soviet Union are diverse and extraordinarily productive and the natural fertility of the soil meet the people's needs for a very long period. Now this intrinsic fertility is being actively supplemented with fertilisers and meliorations.

Up to 70 per cent of the country's land resources consist of deserts and land situated in arid or cold climates: hence the need for wider use of radical melioration of soils on cultivated and newly developed territories.

At the present time there is 0.90 hectare of arable land per head of the population in the Soviet Union. Let us assume that with average harvests of cereals (12-15 centners per hectare) and the present level of income it will in future be necessary to have on average 1 hectare of arable land per head of the population. The per capita area of pasture and hayfields in the USSR now stands at about 1.5 hectare. The scale of the necessary additional development of land before the year 2000 depends on the rate of growth of the population and the growth of general demand, the rate of increase of crop yield and the size of annual losses of cultivated land.

During the last twenty years the area of arable land per head of the population in the USSR has decreased, chiefly as a result of the rapid growth of the mining, oil extraction and power industries and of urban, rural, industrial, and transport development. Since this trend is likely to continue, we may expect that land of various kinds will be set aside for non-agricultural purposes on an increasing scale. So we are faced with the task of using all available methods to put a brake on the process of waste of the country's productive land.

Special attention must be given to the battle against such factors as deflation and sandstorms. The greater the area of cultivated, irrigated soils in arid regions, the less the effects of deflation of sand and soil. And, conversely, the greater the area under the plough in regions where irrigation is absent, the greater the danger and intensity of sandstorms and wind erosion of arable soils. When 60 or 70 per cent of land is under the plough there are occasional sandstorms in regions of steppe agriculture; when the level of cultivation reaches 80 or 90 per cent, sandstorms are a frequent phenomenon. The need then arises for special meliorative and agrotechnical measures (arboreal plantations, high-stemmed plants on fallow land, foddergrass cultivation, non-turning method of cultivation of soils). Considerable research is needed to clarify

the types of optimal correlation of agricultural land in cultural landscapes and to work out biological and physico-chemical measures for preventing dust storms and water erosion.

If large areas of the steppes are ploughed up and measures to prevent dust storms are not taken in good time, deflation may affect and destroy tens of millions of hectares of arable land (experts put the figure at up to 90 million hectares). A great deal of work is therefore going on in the Soviet Union to prevent these phenomena. Among these measures are the recultivation of waste from the mining industry, agrosylviculture, melioration, protective forestation, introduction of anti-erosion systems of agriculture, and optimisation of the correlation between fallow fields, row crops, grain crops and grass. Efforts to preserve the soil cover must be redoubled in the future.

The growth of population brings with it a demand for increase in agricultural production. Let us suppose that by the end of the century the population of the Soviet Union will be approximately 350 million, which represents an increase of 100 million on the present figure. If harvests remained stable, it would be necessary to develop 33 million hectares of new land every ten years, and over a period of 30 years increase the area of arable land by 100 million hectares; this is clearly not a practical proposition. At the same time we may assume that in 30 years the gross production and annual harvests of agricultural crops will double in the USSR. In future the following yields of agricultural crops will be required in the Soviet Union: cereals—28-30 centners per hectare; sugar beet—300-350 centners; raw cotton—35-40 centners; potatoes—200-300 centners; grasses requiring irrigation—100 centners; grasses not requiring irrigation—50 centners. If the average productivity of 1 hectare is doubled, 0.5 hectare of arable land will be needed per head of the population. An area of 225 million hectares will then be capable of satisfying the needs of the country at the 1970 level even with a population of 450 million. Bearing in mind that the extent to which demand will be satisfied at the end of the century will be much higher than in 1970, the area of arable land may remain at the present level for a general doubling of average harvests. However, the need to introduce correct crop rotations, perennial and fruit crops, forest protective belts and anti-erosion measures, as well as compensation for losses of arable land in the future will necessitate additional development of land. Real doubling of productivity for each hectare and for each

crop cannot be fully guaranteed in all natural zones. It is therefore likely that the country's demand for additional development of land will reach 25-30 million hectares in thirty years time.

The Soviet Union has at its disposal sufficient potentially free land resources. Calculations made by the Ministry of Land Reclamation and Water Conservancy of the USSR and soil scientists show that the possible meliorative reserves of land in the country total about 70 million hectares. I. Gerardi has estimated that, provided that the water of the northern rivers is redirected and various meliorations are carried out in the southern parts of the USSR, the total reserves of land suitable for agriculture will amount to 140 million hectares. Thus, the task of possible expansion of cultivated land can be solved by using reserves of territory suitable for agriculture after irrigation, drainage, chemical, physical, anti-erosion and other melioration.

Water melioration must play an important role in helping to double or treble harvests and the gross production of agriculture. In future the area of drained land is likely to increase to 50-60 million hectares and that of irrigated land—to 35-40 million hectares. Melioration will create the best controlled conditions for obtaining high, stable yields for 40 per cent of the country's arable land.

The development of irrigation will be hampered by the fact that the water resources of the rivers of Soviet Central Asia, the Russian Plain and the Caucasus will have been exhausted by 1985. This is why the question arises of redirecting a part of the flow of the northern river basins to the south in both the European and Asian parts of the Soviet Union. This scientific problem is already being investigated. If part of the flow of the rivers Irtysh and Ob were redirected, the additional irrigation of cereal crops in Northern and Central Kazakhstan would enable the harvests of wheat and barley to be doubled and trebled on former virgin lands. With the help of irrigation it will be possible to develop tens of millions of hectares of land for rice, cotton and other crops in Southern Kazakhstan and the Central Asian republics.

It is equally important to seek scientific and technological solutions and other resources of fresh water for the development of irrigation such as underground waters and sewage, water from glaciers and desalinated seawater. A great deal can be achieved by solving the problem of reducing evaporation of moisture from the surface of the soil and bodies of water. If evaporation of water from the fields were reduced and 100-150 mm of moisture preserved in

the soil in the vegetation period, this would eliminate droughts over many millions of hectares of land used for dry farming and would produce an additional yield of cereals of not less than 10 centners per hectare. On salined irrigated soils this method would facilitate desalinisation.

The Soviet Union is conducting scientific research on the artificial structuring and partial hydrophobisation of soils to reduce evaporation of moisture. It would be equally important to master and control the mechanism of internal soil condensation of moisture so as to improve the supply of water for plants. The results of such research will be extremely useful for fulfilling the task of doubling or trebling agricultural production by the end of the century and may bring about radical changes in agriculture.

Apart from measures to protect cultivated land from erosion and salinisation considerable expansion of the practice of applying mineral fertilisers will be required to guarantee the planned growth of agricultural productivity and provide an increase of the area under the plough. In addition, it will be necessary to make full use of local organic fertilisers, carry out liming of acid soils and gypsuming of structural alkali soils.

In the near future all agricultural crop areas (225-230 million hectares) will require about 340 to 350 kg of mineral fertilisers per hectare. By the end of the century these figures will have to be increased to 550-600 kg per hectare (125-150 kg per hectare in units in force). Given a high level of agriculture and optimisation of the water regime of soils, this amount of fertilisation will enable crop harvests to be doubled or trebled. At the same time it will be possible to apply fertilisers to pastures, meadows, hayfields and fallow grassfields.

A high level of fertilisation will only be used rationally if cereal varieties resistant to lodging are available and agricultural crops are capable of accumulating valuable substances. The task of breeding lodging-resistant plant varieties highly responsive to irrigation and fertilisation for the main agricultural regions of the USSR should be solved long before melioration and the application of chemicals to the soil. The creation of winter wheat varieties which in optimum conditions yield 70 or 80 centners per hectare is a major achievement of Soviet genetics. High-yield varieties of spring wheat must also be produced. Priority must be given to mechanisation and the development of multipurpose farm machinery, roads, granary and storage facilities and the power

supply of state and collective farms. Melioration and application of fertilisers will not of themselves produce any great effect unless these conditions are combined.

Changes are quite likely in the practice of applying nitrogen fertilisers. The task here is to create fundamentally new forms of compounds in which nitrogen is applied to the soil. It is essential to stop nitrogen compounds being carried away into subsoil waters, rivers and lakes (pollution and growth of algae) and prevent the processes of denitrification in which the fertiliser loses its nitrogen and toxic compounds are formed in the soils. New kinds of nitrogen fertilisers should not be washed out of the soil, but be subject to the processes of reduction.

New forms of mineral fertilisers and microfertilisers will be introduced into agricultural practice. We are already familiar with the positive effect of additions of soluble silica on the rice harvests in Japan. The effectiveness of treating poor acid soils with sulphur and magnesium compounds has also been proved. It is to be expected that sodium compounds will prove effective with high yields. Micronutrients such as boron, copper, zinc and molybdenum are already coming into use and their production should be planned on a large scale. Methods must be worked out for increasing the content of carbon dioxide in the layer of air immediately above the fields so as to increase the efficiency of photosynthesis. Organic fertilisers and grass growing are irreplaceable in this context. Biochemical fertilisers such as aminoacids, vitamins and enzymes will find application in the future.

In our view it is quite feasible to double crop yields in the USSR within a period of thirty years. For cereals this means an annual growth of just 0.5 centners per hectare. Cereal crop yields have in fact been doubled over the past 35 years from 7 to 14-15 centners. We have the potential to raise the yield of agricultural crops. Average harvests of grains on crop-testing areas, that is in the presence of efficient agricultural techniques and the necessary amounts of fertilisers, are considerably in excess of average grain harvests over the country as a whole.

The possibility of obtaining harvests of stubble crops is an untapped reserve in Soviet agriculture—a reserve from which a second harvest could be obtained. In the irrigated regions of the southern Ukraine the residual sum of active temperatures is between 2,000° and 3,108° which, if the fields are irrigated, will

enable second and a third harvest of food and fodder crops to be obtained. The practice of repeated sowing in this republic is starting to spread to other regions. Transcaucasia and Central Asia have even greater potentials in this respect. In Azerbaijan a certain amount of experience has been gained in obtaining two harvests of rice.

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Land in the Soviet Union is, like every other natural resource, the property of the whole people. Exclusive state ownership of land and a planned socialist economy create the optimum conditions for scientifically-based, rational use of all land reserves, their conservation and every possible increase in the fertility of the soil.

An example of such a complex approach to the use of land is the Resolution of the CPSU Central Committee and the USSR Council of Ministers (1974) "On Measures for the Further Development of the Agriculture of the Non-Black-Earth Zone of the RSFSR", which coordinates short-term needs and long-term prospects, the interests of agriculture and industry, and takes account of social and, specifically, demographic questions. This is in essence a program for the comprehensive development of a vast region of the Soviet Union until the year 1990.

Along with measures to protect soils and increase their productivity the Soviet Union is developing and implementing special state measures to protect and improve existing agricultural land both through melioration and rationalisation of their use, and through strict control over the cultivation of soils, their use for construction purposes, flooding and pollution. Rural and urban construction is becoming increasingly orientated towards wide use of inconvenient and unproductive land. Alienation of productive land should as a result of these measures be reduced to a minimum and compensated for by the melioration and reclamation of currently unproductive territories.

Soviet scientists are at present concentrating much of their attention on the scientific substantiation of methods of restoring and recultivating soils which have been destroyed or degraded. This is a new field of research in which international cooperation and the generalisation of different countries' experience are of particular significance.

The greatest damage to the Soviet Union's land resources comes from the flooding of land by reservoirs, construction of and

alienation by factories and transport facilities, water and wind erosion, and bogging and salinisation of soils due to errors or deficiencies in meliorations and in methods of land reclamation.

In 1975 the USSR Council of Ministers adopted a special resolution "On Measures to Improve the Organisation of Work to Protect the Soil from Wind and Water Erosion", which envisages the implementation on land affected by erosion of a complex of organisational, economic, agrotechnical, forest meliorative and hydrotechnical measures to combat erosion and landsliding. In particular the tenth five-year plan calls for the construction of 750 million rubles' worth of anti-erosion hydrotechnical and soil-fixing installations.

Soviet scientists and production workers are faced with the task of developing and implementing a system of state measures to stop the destruction and waste of the country's land resources. These measures will be based on the principle of universal complex planning of the rational use of land resources for the needs of agriculture and all other sectors of the economy.

The materials of the 25th Congress of the CPSU underline the vast potential for expanding and intensifying agriculture which lies in land reclamation. By 1980 another nine million hectares will be added to the 25 million hectares of improved land in the USSR. The use of chemicals will also account for a large part of the increase in agricultural productivity during the new five-year plan. Between 1976 and 1980 agriculture will be supplied with some 467 million tons of mineral fertiliser, or one and a half times as much as in the period 1971-75. It is planned to increase agricultural production by average 14-17 per cent per annum in the new five-year plan.

The 25th Congress of the CPSU pointed out the need to approach both industry and agriculture from the point of view of protecting the environment. The General Secretary of the Central Committee of the CPSU L. I. Brezhnev noted that "...we must regard agriculture as a huge, constantly operating mechanism for protecting and cultivating living natural resources. And nature will repay us a hundredfold".[1]

[1] L. I. Brezhnev, *Report of the CPSU Central Committee on the Immediate Tasks of the Party in Home and Foreign Policy, 25th Congress of the CPSU*, Moscow, 1976, p. 93.

THE "TECHNICALISATION" OF THE ENVIRONMENT AND MAN'S HEALTH

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Under the conditions of the scientific and technological revolution, which influences all spheres of modern life—from production activity to man's spiritual life—the sociosanitary aspects of environmental change are of considerable importance. The growing rate of this change may provoke a disturbance of the ecological equilibrium between man and the environment. As a result, there may be a reduction in man's adaptative-compensatory abilities and a corresponding increase in the incidence of disease.

The potential of modern society to affect the environment has reached such a level that the results of this influence and particularly errors may have irreversible detrimental effects on people's health.

It can be said in the most general respect that disease springs from a definite contradiction between man's biological and social substrata. The principal means of protecting the population's health is through cognition of man's biological substratum in organic unity with his social being, and transformation of the social environment with due regard for the biological features and requirements of the organism.

The call for man to "get back to nature" is often made in the West as a condition for the maintenance of man's health. Whereas in the 18th century this demand was an expression and manifestation of the romantic revolt against the developing bourgeois system, today it represents an inadequate reaction to growing urbanisation which is becoming an almost universal phenomenon. What we need is not simply a return to nature (in this form a return to nature would be reactionary—a rejection of civilisation's modern achievements), but a new attitude to nature

and its transformation in line with the somatic and neurophysiological potential of the human organism.

In the age of progressing industrialisation and technicalisation of medicine changes are occurring in the nature of the work done by those involved in medicine. Doctors have to resort to increasingly indirect methods of studying the patient. In place of the old principle of the "doctor-patient" interaction we see the evolution of a "doctor-instrument-patient" relationship. The industrialisation of medicine, its technical equipment, is proceeding at an unprecedented rate. Whereas in the past the instruments used in medicine played only a subsidiary role, today they are becoming one of the most important means of cognition. The role of the instrument in medicine began to increase from the moment the transition was made from purely visual observation of pathological processes to the study of their profound, internal structural and functional links and relations.

In studying phenomena on a biomolecular and submolecular level the researcher is concerned not so much with phenomena and processes magnified and intensified by an instrument, as with the readings of these instruments transposed in the form of various kinds of graphs, waves, etc. But such indirect, transformed observation allows the researcher to "project" knowledge onto real processes and phenomena and make conclusions which concord with the pathological picture studied.

Insufficiency of direct observation and the cognition of increasingly complex objects enhance the importance of abstract-logical thought in the apprehension of medicobiological phenomena. This progressive trend in modern medicine does, however, have certain shady, undesirable consequences: an instrument does not give a picture of the patient's personality or his complex sociomental and moral world of experiences and aspirations. The individualised doctor-patient relationship may be subject to a kind of machine-made standardisation and impersonalisation. But the principle of individualisation in treatment presupposes not only a knowledge of the patient, but a knowledge of the phase of development of the particular illness and the kind of psychoemotional reaction shown by the patient. For this modern medicine needs to use complex approaches based on the methodology of dialectical materialism.

Increasing use of accurate, quantitative methods of studying normal and pathological processes is a feature of the development

of modern medicine. A qualitatively new stage is now at hand in the use of physicomathematical, quantitative methods. Whereas in the past quantitative mathematical methods were applied most frequently for technical calculations of a practical nature, today they are used in heuristic research.

But the use of quantification, that is, quantitative "measurement" of qualitative signs (symptoms, syndromes, etc.) in studying the organism as a self-regulating system presents a number of difficulties in methodology.

As we know, mathematical formalism has been developed by generalising the spatial and quantitative properties and relations of objects and processes in inanimate nature. The living organism as a self-regulating system, however, consists of a mass of subsystems which include numerous variable magnitudes functioning in accordance with the probability law. Thus to apprehend the specifics of pathological objects the existing mathematical formalism should be modified and adapted to a more adequate reflection of the specific features of their development.

In clinical medicine a tremendously important role is played by various shades of pathological processes to detect which the clinicist surgeon establishes contact with the patient's personality. This is why, however valuable they may be, mathematical and cybernetic methods can only perform an auxiliary role in the work of the clinicist surgeon. Doctors often have to talk about the qualitative aspect of disease in the language of qualities. For a certain period of time doctor and patient form an indissoluble psychological unity. The success of the treatment often depends on the degree to which this unity is attained.

Whatever the level of technical equipment medicine must always be a science of the individual. In addition to the "technical categories" one should always take account of the "sociological coefficient". This is the best guarantee that a fetish is not made of technicism. Technical equipment and individual clinical investigation in medicine should develop on a friendly rather than competitive basis. They should not go outside a state of "competitive cooperation".

The entry of medicine into the general stream of scientific and technological progress has also produced a number of problems of an ethical nature, such as the social and moral issues which arise in the transplantation of organs and tissues, the problems of medical genetics and psychopharmacology, clinical experimentation, etc.

The increasing differentiation and narrow specialisation in medicine produce contradictions between the facts accumulated and the extent to which they are generalised. There are now some 300 relatively independent branches of medical knowledge. This process, which is on the whole progressive, may under certain circumstances also produce undesirable consequences.

All this demands urgent improvement of the principles of coordination, planning and forecasting in the development of medical science and in the training of doctors.

As this "ascertaining" stage is passed and the transition is made to an explanatory, generalising position in medical science, development of problems of the science of science, particularly the methodology, psychology and sociology of scientific research and scientific thought become especially significant. Methods of scientific research should be more purposeful and take account of the functioning of the internal laws of science studied by means of the sociology and psychology of scientific endeavour.

One of the most important manifestations of the intensifying scientific and technological revolution is the transformation of science into a direct productive force. If one analyses this process under the angle of such a social criterion as increase in labour productivity, which is a criterion of generalisation, then it is right to regard medicine also as a science that to some extent performs the function of a productive force of society. Medicine and public health services, which in socialist society set out to fortify the health of the working population—a most important subjective factor of production—promote the growth of labour productivity. By performing their humanistic, social-sanitary and professional functions medical workers promote the reproduction of a fit work force, and help prolong the active working life of the population.

Whereas, on becoming a direct productive force, sciences of a physicochemical nature act mainly on the material aspect of productive forces (the creation of new substances and technological processes), medicine, like certain other sciences concerned with the study of man, acts primarily on the subjective factor of production.

Although no material production ensues from the activity of medical workers, it still promotes the development of productive forces through the reproduction of a fit labour force and the prolongation of the population's working life. This in turn creates the necessary preconditions for a growth of the product of social

labour and the national income. The activity of medical workers, which is directed towards preserving and fortifying people's health as the most important element of productive forces, must be regarded as a factor in the economic and social progress of society.

Under present-day conditions health occupies an increasingly important place in the hierarchal system of social values. It is one of the indices of national prosperity. WHO experts consider health as one of the twelve most important factors determining the prosperity of the population. Value orientation as regards health acquires increasing importance in conditions in which science is becoming a direct productive force.

The modern scientific and technological revolution is changing qualitatively its demands on the use of man's energy. The rapid rates of complexification of technology and industrial-technological processes, automation and small and large-scale mechanisation of production have been accompanied by a relative reduction in the use of physical, muscular labour by man, and increasing use of brain work and nervous and mental energy in the process of production. In actual fact the fatigue of a man working at a modern assembly line depends not so much on the degree of muscular or physical load, as on nervous and mental exhaustion, the intensity and nature of the various irritants acting on him, on the speed of neuropsychic reactions.

The current stage of social development is marked by an increase in socioeconomic, production-technological, cultural, scientific, psychological and other rhythms of life. In particular, there has been a sharp increase in the rate of operation of lathes, machines and apparatus. As a result of increased technological speeds, new, more complex demands are made on man, on his "working mechanisms", especially the sense organs. The speeds of the organism's psychophysiological and somatic reactions are often insufficient because of their relative slowness in comparison to the high speeds of mechanisms and apparatus. Greater demands on man and the worker's feelings of personal responsibility in changed working processes intensify psychoemotional strain.

Man's health and productivity depend on the degree to which he is adjusted to his environment (in the broad sense of the word, including "artificial" environments such as those in industry). As long as the rhythms of psychophysiological and technological processes more or less corresponded, it was sufficient to have "spontaneous" biological tuning of the organism to changes in

technological and production processes. Now that there is a certain disharmony, however, with the former often lagging behind the latter, special measures must be developed to eliminate the undesirable effects of such lack of rhythm. Psychology, physiology and ergonomics now have the task of developing measures that would guarantee the correct correlation between psychophysiological and technological rhythms without harming the health of the worker.

The correlation of the aims and tasks of production, planning and design with the requirements of labour and health protection is one of the most important sociosanitary principles of the development of socialist production.

Technological progress presents medicine with new tasks all the time. So medicine should proceed from the fundamental laws and features of the development of society and production, and take account of the specific nature of various technological processes. We know, for example, that the mechanisation and automation of production has a certain rhythm, that is, a periodic, often fixed recurrence of movements and working operations. This rhythm should correspond to the laws governing the physiological rhythm of the human organism. Modern labour physiology proceeds from the fact that rhythm helps to develop and strengthen the working stereotype and creates favourable conditions for the most effective coordination of blood circulation and respiration.

As a result of scientific and technological progress, we are witnessing the creation of a new material and technical, chemical, radiational and psychoemotional environment. The biosphere which nurtured our ancestors is becoming a technosphere for modern man.

For centuries people took from nature everything that enabled them to raise their level of technical equipment and paid little heed to the effects that this might have on health. We know that environmental changes brought about by man (uncontrolled, scientifically unforeseen changes) are often unfavourable. In pointing out this fact Soviet scientists note that the limits within which life in general and human life in particular are possible are very narrow in comparison with the broad spectrum of changes which may occur in any environmental parameters. On the reading scale of sanitary characteristics of the conditions of the environment the "comfort zone" is very narrow and the amplitude of possible fluctuations in each of these conditions extremely large.

The task now is to create a new science of hygiene—geohygienics, which would study the various changes in the sanitary characteristics of the environment that are of global proportions.

From the technical point of view man has almost unlimited opportunities for transforming the environment. But apart from practical considerations of utility and consumption the transformation of the environment must be based on sociosanitary expediency. In transforming nature man does not free himself from the operation of its laws.

In other words, the intensive scientific and technological transformation of the environment should be based on a harmonious combination of the proximate goals pursued by man and possible long-term results. Nature should be regarded as an object not just of economic significance, but of great hygienic, sanitary, educational and aesthetic importance.

For socialist society to be successful in using the results of the scientific and technological revolution it is essential that, social and sociohygienic forecasts do not lag behind economic, technical and production forecasts, but light the way and determine the strategic direction of technological progress. Under modern conditions forecasting of environmental changes, their social consequences and control of these processes in the interests of man's health are assuming growing importance.

Forecasting should help predict those consequences of environmental change which have positive and negative effects on people's health. The task consists not only of witnessing the appearance in the environment of factors unfavourable to man's health, but of foreseeing in good time their appearance and having the opportunity of taking essential and timely measures to render them harmless or neutralise them.

If the nature of long-term effects, including those on sanitation and hygiene is not taken account of in the transformation of the environment, future generations will have to pay for our shortsightedness not only in terms of the vast material expenditure needed for various "alterations" and "improvements", but in terms of their health. Maintaining man's environment in the best possible sanitary and hygienic conditions is one of the most important tasks of modern science and economic and industrial practice.

In transforming the environment and creating new socio-economic conditions man does not always and not immediately

recognise and reveal the place and role of several pathogenic factors. As a result of the new socioeconomic conditions these factors may stimulate and spread a number of diseases, primarily social illnesses (neuroses, psychoses, cardiovascular diseases, etc.). Modern pathology is to some extent a consequence of urbanisation, the furnishing of labour and everyday life with machines and high-speed transport; a consequence of man's population of zones having natural centres of disease, or areas with unusual climatic conditions; a consequence of the wide use under certain conditions of dangerous natural minerals, synthetic poisons, including medicines, the latter being frequently abused in everyday life (mainly through widespread and obtrusive advertising).

Man's influence on nature reaches such proportions that the natural regulators and buffer mechanisms can no longer neutralise many of the harmful consequences of this influence.

Pollution has now assumed such a high density in a number of cities in the capitalist world that experts have been forced to admit to a shortage of pure oxygen for breathing. All this has brought about an increase in the incidence of diseases, such as lung cancer, emphysema, bronchitis and asthma.

Imperialism creates unhygienic living conditions not only for the working population at home, but for the peoples of the developing countries and peoples struggling for their liberation. US imperialist aggression against Vietham, Laos and Cambodia had, for example, extremely dire consequences for the environment in those countries.

As we have already stated, there is a limit to which the human organism can accommodate itself to deteriorating environmental conditions. It should be remembered that normal human life in a transformed environment does not proceed through radical change of the structural and functional principles of the organism, but as a result of the environment's adjustment to man's needs. Thus, the strategic principle of the transformation of the environment is to adapt it to the optimum hygienic requirements of the human organism.

Man does not have corresponding adaptative reactions to some new factors in the environment. Figures show, for example, that the number of people with defective hearing in cities is constantly on the increase. This may be due to the fact that apart from the impact of industrial noise, people are affected by the general

hubbub of the city. It is also known that the incidence of lung cancer is higher in cities than in the country.

It is impossible to understand the nature of the pathology of modern man in isolation from the changes occuring in society. Let us take for example urbanisation, which is becoming an increasingly widespread phenomenon. One consequence of urbanisation is the increase in the urban population caused not so much by its natural growth as by migration from rural areas. The role of urbanisation is extremely contradictory as regards health. On the one hand, it produces a certain rise in the standard of life and on the other engenders new diseases or fosters the growth of those diseases which were not frequent in the past such as cardiovascular diseases, cancer, traumatism and mental illness.

Extensive research over the past few years has indicated the presence of a definite link between the people's way of life in a particular settlement and the features of diseases. Certain chronic non-specific diseases reflect the influence of the "urban factor" on the population's disease rate. Specifically the increase in chronic pulmonary diseases is linked more and more often with such factors as the increased population density in cities, and pollution of the atmosphere.

People's psychoemotional relationships become increasingly complicated on transition from one stage of social development to another. All the channels of their emotional intercommunication are filled and sometimes even overloaded. Man's nervous system is subjected to a constant and increasing "bombardment" from all kinds of emotional and psychical factors, both those beneficial to the health and undesirable, negative and even pathological factors. Machinery and even certain occupations are becoming obsolete in shorter periods; development in such spheres as technology and culture is proceeding at an increasing rate. All this makes new, greater demands on man's "inner resources". His mental health, his emotional equilibrium is an important component of these resources. This is why the psychosomatic problem is assuming particular significance.

In the age of rapid scientific and technological progress, tremendous socioeconomic changes and space exploration, the role of the mental factor has grown incredibly in all spheres of life. Whereas in the past the source of psychoemotional disorders lay mainly in the sphere of everyday life and people's personal relations, today the position has changed dramatically. In the

scientific and technological revolution we are seeing the intellectualisation of labour, that is, labour is increasingly embracing elements of intellectual work; man's responsibility for his work is increasing, as are the demands on all his organs and systems of organs.

The psychosomatic problem is becoming especially important nowadays not only because of the influence of the scientific and technological revolution but as a result of the tremendous social changes which have taken place. The process of urbanisation, the accumulation of millions of people in cities, their inclusion in social production, the development of the mass communication media and the never-ending stream of information which passes through man's mind—all this increasingly "psychologises" his life. A contributory factor in this process is modern production which demands a constant increase of the general education and specialised training of the working population.

The process of "psychologisation" of modern life is changing the nature of the psychosomatic problem today. It is natural that man, who has more frequent contact with "psychic" factors in his life, is subjected to an increasing extent to their negative influence. The intensification of people's emotional life means an increased mental load which in some cases leads to neuropsychic overloading.

The humanisation of people's relations in conditions of micro- and macro-communities and the creation of a proper psychological climate have, apart from results in production and the economy (increase of productivity, reduction of the fluctuation of manpower, etc.), a positive sociohygienic significance, as they help preserve and fortify the health of members of socialist society.

Bourgeois literature propagates the idea that the intensification of man's way of life under the conditions of the scientific and technological revolution inevitably makes people neurotic and that any attempt to adapt themselves to an accelerated rhythm of life produces various types of neurotics and psychoneurotics.

In fact, as a result of a special investigation carried out by American doctors, it was established that about 60 per cent of the adult population in the USA had some sort of "mental rift" caused by the features of the American way of life. The growing feeling of fear and uncertainty about the future is one of the dominating features of the working man's mental make-up in capitalist society.

There is no doubt that the intensification of all aspects of man's life in conditions of exploitation and nagging uncertainty in both

the long and the short term produce a systematic increase in neuropsychic disorders. But it would be wrong to extrapolate this feature, which is inherent in the exploiter society, to any society developing under conditions of scientific and technological progress, as do the adherents of the theory of the "single industrial society" and its medical variety—the theory of the "diseases of civilisation".

Of particular significance today is the safeguarding of the mental and moral health of children since the information channels linking children and teenagers with society (school, the cinema, radio, television, etc.) are often overloaded. In capitalist society these channels often carry information which makes young people neurotic, disturbs their mental health and shatters their moral principles.

Representatives of "medical futurology" believe that the next few decades will see a number of medical discoveries and significant advances in the fight against infections, cancer and other diseases; there will be more likelihood of genetic control, the predetermination and regulation of the sex of babies, the development and implantation of artificial organs, and pharmacological action on the memory, on the productivity of physical and brain work, achievements in sport, etc. It is assumed that over the next 70 or 80 years it will be possible to increase the span of life by about 50 years, that is, a decisive step will be taken to bring the real life span up to what is biologically feasible. If these forecasts prove correct, medicine and public health services will have an increased role to play in the life of man and society as a whole.

With the progress of society, and science and technology the framework of the doctor's moral responsibility to people and society is broadening; it is going beyond the bounds of traditional medical humanism.

The transformation of the environment, the introduction of new substances and energy sources, demographic changes and the achievements of genetics, psychopharmacology, etc.—all this gives rise to problems which it is impossible to resolve in a qualified way and from a humane and civil standpoint of social hygiene without doctors' participation.

The genetics of modern man is another problem which cannot be considered in isolation from the social and scientific and technological changes occurring in the world. Such factors as the

development of transport and the means of communication, intensification of migration and the raising of the level of culture, the destruction of traditional religious foundations and the lowering of national barriers have led to a considerable growth in the number of marriages between representatives of different races, nationalities and natural climatic zones. All this tends to undermine and destroy at an increasing rate not just ethnic, but to some extent people's genetic isolation and separation. The genetic "losses" associated with the disappearance or sharp decline in the action of natural selection in human society are counterbalanced by the destruction of genetic isolation.

Scientific and technological advances have paved the way for controlled medical action on man's development so as to prolong his life. This should, however, go hand in hand with an increase in the creative, reproductive period of man's life. Measures are needed to reduce to a minimum the contradiction between the accelerated process of "aging" of the population in developed countries and reduction in the able-bodied part of the population. "Aging" of the population in these countries may reach an even higher level if cures are found for some of the old-age—cardiovascular diseases and cancer.

Scientific and technological progress has also raised a number of problems of an ethical and moral nature. Today we are seeing an increase not only in scientists' role in society, but in their responsibility for the social consequences of their discoveries and experiments.

We know how acute are the ethical problems which have arisen as a result of the development of medical genetics, the transplantation of organs and tissues and other scientific achievements of recent years. Future prospects for the development of neuropharmacology, immunology and medical genetics are increasingly dependent on having a moral substantiation of possible future results and discoveries of science. Such advances as the action of neuropharmacological and physicotechnical means on brain mechanisms, experiments with "vegetative reproduction" of living beings and the development of the embryo *in vitro*, and the achievements of human genetics have presented scientists with the vital problem of the correlation between the prospects of scientific development and the traditional demands of morals, although this is not a new problem. This has always been a constant companion of science. The progress of society, science and technology will

always create collisions between scientific opportunities and moral principles. Each time these collisions will require new approaches and cautious solutions. Success in solving the problems of the future depends on how skilfully and unconventionally we can solve the problems of today. Science provides man with the opportunity of "correcting" certain errors of nature, an opportunity which is steadily growing. And we must be ready to use them without being driven to the extreme of total rejection of the new, or to the other extreme—hasty implementation of scientific achievements which have not been exhaustively tested by life. This is particularly important for medicine since it is concerned with man, his life and health.

The doctor-patient relationship is also undergoing change in the conditions of the current scientific and technological revolution. As we have already mentioned, the level of indirectness of information on the patient's state of health is increasing all the time. The reduction in direct contact between doctor and patient results from the increase in laboratory and diagnostic information and the need to analyse it. The growing differentiation and specialisation in medicine creates a situation in which the patient is seen not by one doctor, as was the case in the past, but by a number of doctors, who often examine him in terms of their own narrow field. Moral responsibility for the patient's state of health is also "distributed" among numerous doctors. In these circumstances the task emerges of finding adequate forms of synthesis in the study of the patient's condition and increasing the level of responsibility on the part of each "narrow" specialist for his state of health.

By falsifying the conclusions regarding the impact of scientific and technological progress on the population's health bourgeois ideologists attempt to explain from their own standpoint many problems of modern public health. In recent years various "theories of adaptation" have been propagated on an increasing scale in the West. Their essence is as follows: man cannot attain the optimum as regards health through changing in a revolutionary way the socioeconomic conditions of capitalism, but by adapting the neurophysiological and other features of man's organism to an environment changing at an increasingly rapid rate.

Basing themselves on the presence of real contradiction between psychophysiological (biological) and technological (social) rhythms, the disharmony between the rhythms of man's life and the rhythms arising in the "artificial" environment some bourgeois scientists

have developed a theory which explains the reasons for the origin and widespread occurrence of a number of diseases under modern conditions. According to the authors and advocates of the theory of social disintegration, civilisation deprives man of his normal ecological conditions of life; in the course of evolution he developed certain adaptational (physiological and neuropsychological) mechanisms so as to adjust himself to these conditions.

By proving the existence of common conditions in which diseases arise and their general, total laws of development seemingly included in the "disharmony of biology and sociology", the adherents of this theory call all the diseases supposedly engendered by this arrhythmia "diseases of modern civilisation". But here the specific class and economic nature of the particular society is hidden behind the term "civilisation". In regarding the level of urbanisation and industrial development as the only criterion of "civilisation" they deny the fundamentally different consequences of the impact which capitalist and socialist society has on the health and incidence of disease among the population.

The concept of "diseases of modern civilisation" is essentially a medical version of the reactionary "single industrial society" theory. Proponents of this theory attempt to lay a foundation for the "convergence" of socialism and capitalism in all spheres of life including public health.

It is in modern capitalist society itself that living and working conditions are becoming increasingly inhumane. The process of so-called alienation is gathering pace, as is the contraposition of man, on the one hand, and economics, politics, technology and culture, on the other. Such a position creates a mood of emotional bankruptcy, depression and existentialist hopelessness.

By isolating the problem of alienation from its socioeconomic basis, bourgeois ideologists attempt to "humanise" living and working conditions with the aid of so-called "human relations" within the framework of the capitalist system.

The establishment of a correspondence between technology and man's neurophysiological potential is one of the requirements of the "human relations" concept. But in capitalist society this requirement is often realised in practice by removing an increasing number of people from the sphere of intensified production. In other words, from the bulk of the workers are selected only those who conform to the increased demands made by modern

technology. The majority of them replenish the army of unemployed, the lumpen proletariat.

Under capitalism the scientific and technological revolution instills in people a feeling of uncertainty in the near future, harms their psychic make-up and undermines mental health. The scientific and technological revolution increases the rate at which not just machines, lathes and equipment but trades and professions become obsolete. The need to constantly improve its professional standard and sometimes to change professions lays a heavy burden on the budget of the proletarian family. Expenditure on professional advancement is more often than not made by reducing expenditure on food and other vital needs. So-called "age discrimination" is manifested in one form or another in all industrial capitalist countries. If one takes account of the "aging" of the population, that is, the increase in the proportion of middle-aged people in the population as a whole, then a tragic future is in store for a considerable section of the working population in these countries. The intensification of labour in capitalist enterprises is accompanied by an incredibly high rate and rhythm of production, in excess of the physiological potential of man's cardiovascular and neuropsychic systems.

There is now a deepening contradiction between the opportunities presented by medical science and technology in the fight against disease and its prevention, and their availability to broad sections of the population in an exploiter society.

Because of the growing role of medicine in the life of modern man bourgeois ideologists attempt to use its facts and achievements for ideological speculation of various kinds. All fundamental bourgeois philosophical and sociological trends are represented in the theory of medicine, particularly in interpreting the problem of health and diseases which is a kind of focal point of the ideological struggle in medicine.

Various aspects of technological progress receive a one-sided and often distorted interpretation in these trends. In particular, the apologists of technological determinism usually consider technological progress as the cause of a number of diseases regardless of social system. They try in this way to absolve capitalism from its responsibility for the deterioration of the health of the working population. At the same time they preach that prevalence of disease is inevitable, and supposedly predetermined on a growing scale by technological progress.

What has been said above indicates, however, that scientific and technological progress is not an autonomous process. Its social and sociohygienic consequences are determined by the sociopolitical system of the society in question.

It is only under socialism, where the social, economic and sociohygienic aims and interests of all classes and their state coincide, that scientific and technological progress foster the health and well-being of man. Even those negative sociohygienic consequences of the "technicalisation" of the environment which sometimes arise can be and are being successfully overcome in socialist society with its planned economy.

APPENDICES

DECISION OF THE SUPREME SOVIET OF THE USSR ON MEASURES TO FURTHER IMPROVE NATURE CONSERVATION AND THE RATIONAL UTILISATION OF NATURAL RESOURCES

September 20, 1972

The protection of nature and the rational use of natural resources under conditions of the rapid development of industry, transport and agriculture, the spread of the scientific and technological revolution, and the growth of the diverse material and cultural needs of the Soviet people is becoming one of the most important national tasks on whose solution depends the successful fulfilment of economic plans, and the prosperity of present and future generations. The solution of this task in socialist society is inseparably linked with the protection of the population's health and with the guarantee of the necessary conditions for Soviet people's fruitful work and recreation.

In the Soviet Union socialist state ownership of land, mineral resources, water and forests forms a solid foundation for the organisation of the most rational use of natural resources and the effective protection of nature. It is precisely in these conditions that planned control of the economy and high rates of economic development are guaranteed.

The management, conservation and reproduction of natural resources, and a careful attitude to nature are a component part of the program for the construction of communism in the USSR. The Communist Party and the Soviet State display a tireless concern for the protection of nature and the rational use of its resources.

The 24th Congress of the Communist Party of the Soviet Union outlined the major tasks for strengthening the protection of nature in the country and increasing the responsibility of ministries, departments, institutions and organisations for the rational use of natural resources. This was reflected in the USSR State Five-Year Economic Development Plan for 1971-75. Of great significance in resolving the tasks of improving the protection of nature and the

rational use of the country's natural resources are the recently-passed Principles of Land Legislation of the USSR and the Union Republics, the Principles of Water Legislation of the USSR and the Union Republics, the Principles of Legislation of the USSR and the Union Republics on Public Health, and the corresponding laws and codes of the Union Republics.

In carrying out the measures outlined on the protection of the natural environment the Soviet Union constantly expands its cooperation in this matter with foreign states and international organisations and guarantees the fulfilment of the obligations which it has undertaken.

The Supreme Soviet of the USSR notes that the Soviet Union consistently implements measures aimed at improving the protection of nature and guaranteeing the rational use of natural resources.

Large-scale work is proceeding on the reclamation of land, and on the prevention of wind and water erosion of soils; the use of water resources, forests and minerals is being improved. Valuable and rare species of animals have been taken under the protection of the state and the control of fisheries is being improved. Serious attention is being given to measures on the prevention of air and water pollution, the improvement of gas and central heating systems in towns and other population centres, and the fight against noise. There has been a considerable increase in the amount of capital investment on the implementation of measures on the protection of nature, and on the construction of installations for treating sewage and gas-purification and dust-extraction installations.

The further development of the economy and the drawing of natural resources into production in increasing proportions demand from all state and public organisations increased attention to the protection of nature, improvement of the use of natural resources, and elimination of the serious shortcomings that exist in this field.

Some ministries, departments, local Soviets of Working Peoples' Deputies, enterprises and organisations still do not take due account of these demands and do not concern themselves in the requisite way with the questions of guaranteeing the rational use of natural resources and the protection of nature. Ministries, departments, enterprises and organisations do not fully observe legislation on the complex use of mineral resources and permit

considerable losses of minerals during extraction and processing. Frequently, just the basic metals are extracted from mineral ores and a considerable part of the valuable accompanying elements are thrown onto dumps, which does a great deal of harm to the state.

In industry technological processes are slowly being developed and introduced so as to secure a considerable reduction in the consumption of water on production needs and the amount of harmful wastes which have a detrimental effect on the state of the natural environment. Many enterprises and a number of towns lack the necessary installations for treating sewage, are building such installations at a slow pace, and are not using fully the funds allocated for these purposes. The necessary purification of industrial emissions released into the atmosphere is not guaranteed, nor are a sufficient number of gas-purification and dust-extraction devices and installations being manufactured.

In the solution of civil engineering problems and the development of rural areas due attention is not always paid to creating the optimal conditions for the life, work and recreation of the population.

There have been cases of wasteful attitudes to the country's main resource—land, facts revealing the irrational use of agricultural and forest land, and the incorrect exploitation of water reservoirs. Erosion and repeated salting of soil, mining and construction often exclude large areas of fertile land from agricultural use.

The Councils of Ministers of the Union Republics and the ministries and departments of the USSR who have been charged with the state supervision and control over the observance of legislation on the protection of nature and the use of natural resources are not paying the requisite attention to the fulfilment of the tasks set them in this field.

The local Soviets of Working Peoples' Deputies are still not showing due concern for the rational use of land, agricultural and forest areas and waters and exercising insufficient control over the implementation of measures to increase the fertility of the soil and protect the animal and plant worlds.

Scientific research organisations called on to deal with urgent problems of the multipurpose use of natural resources and the protection of the natural environment are also failing to fulfil their tasks satisfactorily.

The Supreme Soviet of the USSR underlines that with the achievements of the scientific and technological revolution and the

powerful base of our industry it is possible in the conditions of the socialist economy to make intelligent use of all natural resources and to resolve successfully an historically important task—the neutralisation of the side-effects of economic activity which are harmful to nature and man.

The multipurpose use of natural resources, the introduction of wasteless technological processes, the wider application of biological means of water treatment and pest control, afforestation and land-reclamation work—these and other measures can guarantee an effective defence for the environment. Therefore the further development of the economy of the Soviet Union as a whole and of various sectors of the economy taken separately should be based on thorough-going, multidisciplinary research and be backed by scientific forecasts of possible consequences and an obligatory system of measures excluding any harmful effects on the natural environment. Our task is to preserve and multiply all the riches and amenities of nature for the generations that will live in communist society.

The Supreme Soviet of the Union of Soviet Socialist Republics decides:

1. To consider as one of the most important state tasks tireless concern for the protection of nature and for the improved management of natural resources, and strict observance of the legislation on the protection of the land, mineral resources, forests, waters, the animal and plant worlds, and the atmosphere, bearing in mind that scientific and technological progress should be combined with a careful attitude to nature and its resources and promote the creation of the most favourable conditions for the life, health, work and recreation of the working population.

2. To commission the Council of Ministers of the USSR to elaborate measures on the further consolidation of nature protection and the improvement of the use of natural resources with regard for the proposals made by the deputies of the Supreme Soviet of the USSR at the session, and the proposals of the commissions on the protection of nature and other standing commissions of the Soviet of the Union and the Soviet of Nationalities of the Supreme Soviet of the USSR. These measures should envisage:

—the improvement of planning aimed at the rational use of natural resources and the protection of nature, allowing for the fact that the outlined nature-protection measures should form an

integral part of the long-term and annual economic development plans;

—increase of the responsibility of ministries, departments, enterprises and organisations for the full, multipurpose use of minerals and mineral resources during their extraction and refinement, strict observance of legislation aimed at a truly thrifty attitude to land and forest areas, water resources and their protection, and increase of the personal responsibility of citizens for conserving the environment;

—strengthening of the responsibility of ministries, departments, enterprises and organisations for the implementation of measures on the prevention of soil pollution by industrial wastes and chemical weeds and pest-killers, pollution of water by industrial and municipal and domestic sewage, and pollution of the atmosphere by industrial emissions and automobile transport exhaust gases, and for the implicit observance of the sanitary and hygiene norms and rules;

—implementation of the requisite measures to prevent air and water pollution, timely construction of treating installations, increase in the quality of construction, elaboration and development of the production of new forms of equipment and devices for gas purification and dust-extraction, the creation of new technological production processes and the improvement of existing ones, and thrifty expenditure of water;

—expansion of the manufacture of machinery, equipment, and control and measurement devices, and increase in automation methods which enable the protection of nature to be improved and effective use to be made of all its resources;

—elaboration of urban development norms guaranteeing the maximum improvement of the environment in industrial and administrative centres;

—expansion of research on the most important problems of the protection of nature and the rational use of natural resources;

—improvement of the education of schoolchildren and students of specialised secondary and higher educational establishments in the field of natural history and the protection of the natural environment, the training and expanded output of highly-qualified experts in this area capable of efficiently and economically involving vast natural resources in the economy;

—the active participation of the USSR in the elaboration and implementation of international cooperation programs in the study

of the natural environment and its protection against untoward influences.

3. That the Councils of Ministers of the Union Republics and the appropriate ministries and departments exercise strict supervision and control over the correct use of natural resources and the protection of nature.

That the local Soviets of Working Peoples' Deputies tighten control over the implementation of measures aimed at achieving rational use of agricultural and forest land, and waters, the protection of the animal and plant kingdoms and the improvement of the sanitary state of cities and other population centres, and at fighting industrial and domestic noise.

4. That on completing the preparation of the draft Principles on Forest Legislation of the USSR and the Union Republics and the Principles of Legislation of the USSR and the Union Republics on Mineral Resources the standing commissions of the Soviet of the Union and the Soviet of Nationalities take account of the proposals and comments made at the session.

THE CENTRAL COMMITTEE OF THE CPSU AND THE COUNCIL OF MINISTERS OF THE USSR ON THE INTENSIFICATION OF NATURE CONSERVATION AND IMPROVED UTILISATION OF NATURAL RESOURCES

At the fourth session of the eighth convocation in September 1972 the Supreme Soviet of the USSR considered the question of measures on intensification of nature conservation and improved utilisation of natural resources and acknowledged as one of the most important state tasks tireless concern for the protection of nature and the improved use of natural resources with the aim of creating the most favourable conditions for the life, health, work and recreation of the working population.

The Central Committee of the CPSU and the Council of Ministers of the USSR adopted a detailed Decree on Intensification of Nature Conservation and Improved Utilisation of Natural Resources which also take account of the proposals made by deputies of the Supreme Soviet of the USSR at this session.

The Decree of the CPSU Central Committee and the Council of Ministers of the USSR notes that measures are being taken in the country to improve the protection of nature and guarantee the rational use of natural resources.

The Decree also notes that many ministries, departments, enterprises and scientific research organisations are still not dealing in the requisite manner with the protection of the natural environment against pollution or ensuring rational use of natural resources, not giving sufficient attention to the development of technological processes which exclude or significantly reduce, the level of pollution of soil, air and water, nor doing the necessary research on improving the methods and technology of sewage treatment, gas purification and on other urgent problems of nature protection and the reproduction of natural resources.

The Central Committee of the CPSU and the Council of Ministers of the USSR invited the Central Committees of the Communist Parties and the Councils of Ministers of the Union

Republics, Party Territorial and Regional Committees, Councils of Ministers of the Autonomous Republics, Territorial and Regional Executive Committees, and ministries and departments of the USSR to give increased attention to the questions of nature conservation and the guarantee of the rational use of natural resources, and to establish systematic control over work to combat the erosion of soil, over the correct use by collective farms, enterprises and organisations of land, water, forests, mineral resources and other natural resources and over the observance by them of the existing rules and norms on the recultivation of land, on the prevention of pollution and salting of soils and surface and subterranean waters, on the conservation of the water-preserving and protective functions of forests and the water-regulating role of peat bogs, on the conservation and reproduction of the animal and plant worlds, and on prevention of air pollution.

The Decree specifies the functions of ministries and departments in the field of nature protection and the provision of the rational use of natural resources; in particular it lays down:

—that the USSR Ministry of Land Reclamation and Water Conservancy exercises state control over the rational use of waters, over the implementation of measures on the protection of bodies of water against pollution, salting and depletion, and over the operation of treatment plants and discharge of sewage;

—that the USSR Ministry of Agriculture exercises state control over the observance of land legislation and land use and bears responsibility for organising the correct application in agriculture of chemical fertilisers and pest and weed-killers, and for the development and broad application of biological means of combatting diseases and pests;

—that the State Committee for Forestry of the USSR Council of Ministers exercises state supervision of the rational use of forest resources in the country, and bears responsibility for the reproduction and increase in productivity of forests, the forest-fire prevention and control, the protection of forests against harmful insects and diseases, and the organisation of the protection of forests from wilful felling and other actions causing damage to the forest;

—that the USSR Ministry of Fisheries ensures the preservation and reproduction of fish reserves, the regulation of fishing and the protection of the natural resources of the country's continental shelf;

—that the State Committee for the Supervision of Safety in Industry and Mining Supervision under the Council of Ministers of the USSR exercises control over the protection of mineral resources and their correct exploitation.

Responsibility for ensuring the implementation of air pollution control in cities and other population centres is borne by the Councils of Ministers of the Union and Autonomous Republics, and regional, territorial and city executive committees. They are also obliged to tighten control over the implementation by all enterprises and organisations, regardless of their departmental subordination, of measures on nature protection and the improvement of the use of natural resources, and over the strict observance by all citizens of the established rules of environmental protection.

The resolution makes provision for measures to improve planning and stock-taking in the field of nature protection and the use of natural resources, to improve the design of industrial enterprises and the planning of towns and other population centres, and to create a state service for observing and controlling the level of pollution of the atmosphere, the soil and bodies of water. In particular the resolution lays down that from 1974 onwards long-term and annual plans should be drawn up on the rational use of natural resources and on the protection of nature as an integral part of the long-term and annual economic development plans.

The Weather Service Administration under the USSR Council of Ministers is invited to organise a state service for observing and controlling the level of pollution of the atmosphere, the soil and bodies of water.

The State Committee of the USSR Council of Ministers for Science and Technology is commissioned to develop, together with the appropriate ministries and departments, and approve plans for scientific research on the rational use of natural resources and nature protection, the coordination of the work of scientific institutions on the development of the most important problems in this field and the provision of finance for the most important scientific research projects envisaged in these plans, and exercise control over their fulfilment.

The State Committee of the USSR Council of Ministers for Science and Technology is commissioned together with the USSR Academy of Sciences to organise an inter-departmental scientific

and technological committee on the complex problems of protecting the natural environment and the rational use of natural resources which is to function under the State Committee for Science and Technology.

The Councils of Ministers of the Union Republics are obliged together with the USSR Ministry of Land Reclamation and Water Conservancy and the USSR Ministry of Fisheries and other interested ministries and departments to elaborate measures ensuring the complete cessation of the release into bodies of water of untreated or insufficiently purified and neutralised sewage, primarily into river basins where a high level of pollution is observed or pressure on the water balance is expected.

The resolution also envisages measures on the broad-scale breeding of plant-eating fish which help improve the biological purification of water from algae and other vegetations harmful to water resources and simultaneously use the large quantity of biogenous substances which accumulate in reservoirs.

Ministries and departments of the USSR and the Councils of Ministers of the Union Republics have been set concrete tasks on the elaboration, development and manufacture of new kinds of equipment and devices for installations which treat the sewage from cities and industrial enterprises, and instruments for controlling the quality of the natural surface waters and sewage, and the task of developing and implementing between 1973 and 1975 new methods of treating sewage.

It is thought necessary to set up inside the Ministry of Chemical and Oil Machine-Building a central administration for developing and manufacturing gas-purification and dust-extraction equipment with a subordinated state inspectorate to control the operation of gas-purification and dust-extraction installations.

The Councils of Ministers of the Union Republics, and ministries and departments of the USSR are commissioned to implement between 1973 and 1975 measures to reduce the toxicity of the exhaust gases of vehicles in exploitation, having particular regard for the organisation in major cities and health resorts of the requisite network of control and regulation posts.

In order to reduce the losses of minerals during their extraction and processing and to prevent environmental pollution by industrial wastes the USSR Ministry of Non-Ferrous Metallurgy, the Ministry of Ferrous Metallurgy and other ministries concerned with the extraction and processing of minerals are obliged to

approve for all subdepartmental enterprises plans to introduce more effective methods and systems for working mineral deposits and technological plans for processing mineral raw materials which ensure the most expedient extraction from the earth of the reserves of minerals and the use of their industrially useful components.

In order to improve the sanitary state of cities, suburban areas, workers' settlements and rural population centres the Councils of Ministers of the Union Republics are suggested to do the following:

—to expand between 1973 and 1980 the area of vegetation in cities and suburban areas (the creation of new parks, gardens, boulevards, and protective green belts and forest parks, particularly on recultivated land);

—to implement in 1973 and 1974 the necessary measures to bring open, unregulated waste dumps near cities, industrial centres and resorts into line with the sanitary regulations approved by the Ministry of Public Health of the USSR;

—to organise the elaboration of design documentation on the construction of waste-processing and waste-burning plants and ensure the construction of such plants in large cities and health resort areas from 1974 onwards;

—to draw up and implement between 1973 and 1975 measures on the organisation of the centralised collection, removal and neutralisation of industrial wastes in large cities and industrial centres, by involving in the accomplishment of these measures enterprises of the appropriate ministries and departments of the USSR.

The Central Committee of the CPSU and the Council of Ministers of the USSR have deemed it necessary to increase among the population the propagation of knowledge on nature protection and explain more widely the importance of the rational use of nature's resources.

The ministries and departments which administer educational institutions are commissioned to put greater accent on the teaching of the fundamentals of natural history, the rational use of natural resources and the protection of the natural environment.

(*Izvestia*, No. 8, January 9, 1973)

DECREE OF THE SUPREME SOVIET OF THE USSR ON MEASURES FOR THE FURTHER STRENGTHENING OF THE PROTECTION OF MINERAL WEALTH AND ITS BETTER USE

July 9, 1975

In conditions of accelerated development of the national economy, and associated involvement of ever-increasing quantities of mineral raw materials in production and the wider use of mineral wealth for other purposes, the tasks of protecting the mineral resources and improving their exploitation acquire special significance. The protection of nature and the rational use of its resources is one of the most urgent problems of contemporary times, on the correct solution of which largely depend the successful development of the economy and also the well-being of the present and coming generations.

The Soviet Union holds a leading place in the world in resources of oil, gas, coal, iron ore, manganese ore, chromium ore, and many non-ferrous and rare metals. Most favourable conditions for the comprehensive, effective and thrifty use of mineral wealth and its protection are created by socialist ownership of this wealth and plan-based economic development.

The Communist Party and the Soviet state are consistently tackling tasks connected with the ensurance of the thrifty use of mineral resources and with the intensification of their protection. The 24th Congress of the CPSU charted an extensive program of undertakings for the better use of mineral raw materials, and expansion of geological study and prospecting of mineral wealth, first of all, in the areas of operating mining enterprises, as well as in areas which economically are most advantageous for their industrial development.

Of essential importance for the implementation of this program are the Decree of the USSR Supreme Soviet and the Decision of the CPSU Central Committee and the USSR Council of Ministers,

adopted in 1972, on questions of intensification of the protection of nature and the better use of natural resources.

The main assignments concerning the protection of mineral wealth and the rational use of mineral resources have been envisaged by the state plans for the development of the national economy of the USSR in the last few years.

The mineral raw materials base of industry has been reinforced considerably by the completion of prospecting of a number of deposits which are of major importance for the national economy, and by the fulfilment of the targets for increasing the known mineral resources.

Progressive systems in working the deposits are being introduced, which ensure a reduced loss of minerals; methods of enrichment and processing of mineral raw materials are being improved, which make it possible to extract valuable components and obtain commercial products from jointly occurring minerals and from minerals mined as a by-product.

The interior of the earth is likewise being increasingly used for the construction of underground oil and gas storage installations, for the construction of tunnels, subways and storehouses, and for other purposes.

Basic and applied researches are being expanded in improving methods of mineral prospecting, extraction and processing, and also in improving the construction and operation of underground installations.

At the same time, the USSR Supreme Soviet notes that there still are some essential shortcomings in the matter of the rational use of mineral resources and their protection.

The Ministries, departments, enterprises and organisations, dealing with the extraction, enrichment and processing of minerals, do not always ensure the observance of the requirements of legislation concerning the rational use of mineral raw materials, and frequently allow sizable losses of minerals. A narrow departmental approach is still being manifested during the working of mineral deposits, and construction of installations ensuring the comprehensive processing of mineral raw materials is proceeding slowly. The ways of extracting certain components from mineral raw materials which are suitable for use in production have not been elaborated till this day. Serious damage is being done to selective extraction of minerals from the richest layers of deposits. As before, a good deal of casinghead gas is wasted during the

development of oil deposits. In individual cases the working of mineral deposits was temporarily postponed because of earlier upbuilding of their surface areas.

In a number of cases, on account of insufficient exploration of deposits and inadequate study of their composition, as well as errors committed when estimating mineral stocks, the blue-printing of mining enterprises is conducted on the basis of incomplete or insufficiently reliable initial information, which leads to gross miscalculations in technical designs and unwarranted losses of materials and money. Some designs of ore mining and concentration plants and metallurgical works do not incorporate measures to ensure the comprehensive utilisation of mineral raw materials. This is also true in those cases when there are confirmed data on the stocks of all useful components of a given deposit.

There is slow progress in solving the problem of reducing the number of small-scale open pits mining commonly occurring minerals. Most of these pits are working unexplored mineral resources, without official recognition of mining rights and allocation of land area, which results in heavy mineral losses. Occasionally such pits take up considerable areas of arable and other farmlands, which as a rule are not put back into cultivation upon the closure of the pits, and the fertile soil layer is, with rar exceptions, not preserved. The executive committees of the local Soviets of Working People's Deputies fail to take necessary measures for amalgamating and closing down small-scale pits.

The Council of Ministers of the Union Republics, the Ministries and departments, the local Soviets of Working People's Deputies, as well as bodies charged with state supervision and control over the observance of the legislation on natural resources, do not pay sufficient attention to the fulfilment of their tasks of improving the protection of natural resources, of promoting the better use of mineral resources and observing legality in the given sphere of social relations.

The Supreme Soviet of the Union of Soviet Socialist Republics resolves:

1. To consider it one of the major national tasks to ensure the rational, comprehensive and economical use of natural resources and to improve their protection for the purpose of further developing the socialist economy and raising the welfare of the Soviet people.

2. The Council of Ministers of the USSR, with due account taken of the suggestions by the standing commissions of the Soviet of the Union and the Soviet of Nationalities, by deputies of the Supreme Soviet of the USSR, is to draft and implement measures for improving the use of mineral resources and improving their protection, bearing in mind the following:

—improvement of planning with the aim of ensuring the rational and comprehensive use of mineral and raw material resources and of promoting the use of the earth's interior for the needs not connected with the mining of minerals;

—improvement of geological examination of the natural resources and enhancement of the efficiency of geological work and reliability of its findings;

—accelerated development and introduction in production of new and highly efficient mining systems and technologies for the processing of mineral raw materials;

—expansion of research and design work on the most important problems relating to the rational use of natural resources and their protection:

—further enhancement of the responsibility of Ministries, departments, enterprises and organisations for the full, comprehensive and effective use of minerals when mining, beneficiating and processing them and for the protection of mineral resources.

3. The Council of Ministers of the Union Republics, the Ministries and departments are to provide proper control and supervision over the correct use of the natural resources, the working of mineral deposits, the protection of natural resources, safety of work connected with the use of these resources, and the protection of the environment against the harmful effect of this work.

4. The local Soviets of Working People's Deputies and their executive committees are to exercise greater control over the proper organisation of the mining of commonly occurring minerals and make wider use of the rights the legislation affords them for control over the use and protection of natural resources.

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The Supreme Soviet of the USSR believes that on the basis of powerful socialist industry and the achievements of the scientific and technological revolution, the USSR has now every possibility to

ensure the effective use of natural resources and their protection. The scientifically substantiated planning of the development of mining industry, the introduction of new technology and progressive methods of mining and processing minerals, strict state supervision and control over the observance of legislation on the rational and comprehensive use of natural resources and their protection, the wide participation of the public in this work will help to fulfil the major national economic and social tasks of the present stage of communist construction.

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